MM3000 Motion Controller/Driver

USER'S MANUAL

Newport

Warranty

Newport Corporation warrants this product to be free from defects in material and workmanship for a period of one year from the date of shipment. If found to be defective during the warranty period, the product will either be repaired or replaced at Newport's option.

To exercise this warranty, write or call your local Newport office or representative, or contact Newport headquarters in Irvine, California. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty period, or at least 90 days.

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Introduction

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Section 1
Introduction

1.1 Safety Considerations

The following general safety precautions must be observed during all phases of operation of this equipment. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards of design, manufacture and intended use of this equipment.

Disconnect AC power under the following circumstances:

— If the power cord or any other attached cables are frayed or damaged in any way.

— If the power plug or receptacle is damaged in any way.

— If the unit is exposed to rain, excessive moisture or liquids are spilled on it.

— If the unit has been dropped or the case is damaged.

— If you suspect service or repair is required.

— Whenever you clean the case.

— When opening the unit for upgrades or setting of switches.

To protect the equipment from damage and avoid hazardous situations, follow these recommendations:

— Do not make any modifications or parts substitutions to the equipment.

— Do not touch, directly or with other objects, live circuits inside the unit.

— Do not operate the unit in an explosive atmosphere.

— Keep all air vents free of dirt and dust and do not block them.

— Keep all liquids away from unit.

— Do not expose equipment to excessive moisture (>85% humidity).

WARNING

All attachment plug receptacles in the vicinity of this unit are to be of the grounding type and properly polarized.
Contact your electrician to check your receptacles.

WARNING

This product is equipped with a 3-wire grounding type plug.
Any interruption of the grounding connection can create an electric shock hazard.
If you are unable to insert the plug into your wall plug receptacle, contact your electrician to perform the necessary alterations to assure that the green (green-yellow) wire is attached to earth ground.

WARNING

This product operates with voltages that can be lethal.
Pushing objects of any kind into cabinet slots or holes, or spilling any liquid on the product, may touch hazardous voltage points or short out parts.

WARNING

Opening or removing covers will expose you to hazardous voltages.
Refer all servicing internal to this controller enclosure to qualified service personnel who should observe the following precautions before proceeding:

- **Turn power OFF and unplug the unit from its power source;**
- **Disconnect all cables;**
- **Remove any jewelry from hands and wrist;**
- **Use only insulated hand tools;**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

1.2 Conventions and Definitions

Symbols And Definitions

The following are definitions of safety and general symbols used on equipment or in this manual.

Chassis ground. Indicates a connection to the controller chassis which includes all exposed metal structures.

WARNING

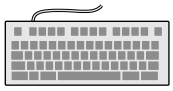
Warning: Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in injury or death.

CAUTION

Caution: Calls attention to a procedure, practice or condition which, if not correctly performed or adhered to, could result in damaging of the equipment.

NOTE

Note: Calls attention to a procedure, practice or condition which is considered important to remember in the context.



Remote Command. Indicates a remote command via RS-232C, IEEE488 or optional handheld keypad equivalent to the local function being described.

Terminology

The following is a brief description of frequently used terms in this manual.

Axis	Logical name for a motion device
Controller	Refers mostly to the MM3000 controller/driver
Encoder	Displacement measuring device, term usually used for both linear an rotary models
Home (position)	Unique point in space that can be accurately found by an axis, sometimes called *origin*
Home Search	Specific motion routine used to determine the home position
Jog	Motion of undertermined duration; usually initiated manualy
Motion Device	Refers to an electro-mechanical motion device
Move	Motion to a destination, initiated manualy or remotely
Origin	Sometimes used instead of *home*
Origin Switch	Switch that determins an approximate point in space. Used in the home search rourine
PID	Closed loop servo algorithm
Remote	Refers to the mode of operation where communication is performed via RS-232C or lEEE488 interface link or with the optional handheld keypad
Stage	Most common type of motion device for the MM3000. Sometimes used instead of *motion device*

1.3 General Description

The MM3000 is a stand-alone integrated motion controller/driver. It can control and drive up to 4 axes of motion, in any stepper and DC motor combination. The MM3000 was specifically designed to operate with Newport's broad line of motion devices. This significantly increases the user friendliness and raises overall performance of a motion system. Using other manufacturer's motion devices is also possible.

A variety of interfaces and input devices allow the user to carry out typical operations in a motion control system. For example, the optional front panel with dedicated displays and push-buttons for each axis can be used for simple motion sequences. The display shows displacement in terms of user-selected units, e.g., encoder counts, microns, mils, degs, etc. In addition, the MM3000 utilizes a menu structure which enables the user to set various system parameters without the use of a computer.

If manual motion through the front panel is not required, the user can choose to have the blank front panel version without display and comunicate with the MM3000 via standard IEEE488 or RS-232C (standard with both versions) with a host computer.

An optional handheld keypad (see Fig. 1.1) that allows access to the full MM3000 command set without the use of a computer is available for either front panel version.

A possible motion system setup is shown in **Fig. 1.1**. In this configuration, the MM3000 drives 4 stages and is controlled by a remote computer. Digital I/Os could be used to trigger certain events and the remote "Motor Off" switch allows the operator to disable any motion remotely.

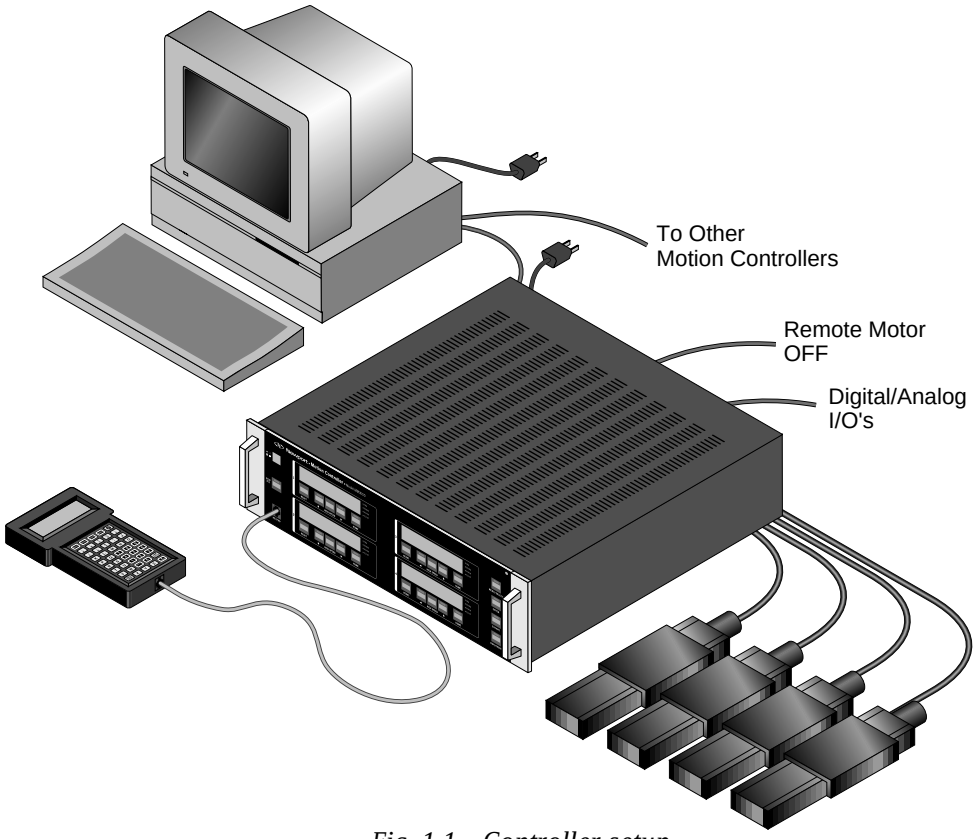


Fig. 1.1—Controller setup

To explore all capabilities of the MM3000 controller and identify the system configuration that best fits your application, please read most of this manual, or contact our experienced applications support group for advice.

1.3.1 Features

A number of advanced features make the MM3000 an excellent choice for many applications:

- Integrated controller and driver design is cost effective and space saving
- Compact, standard 3U height rack mountable or bench-top enclosure (an optional fan unit adds 1U to the height of the MM3000)
- Allows any combination of motor types (stepper and DC) and sizes from the supported list (Appendix C)
- Closed loop operation for stepper motors and DC motors
- Distributed processor architecture
- Real-time high speed command processing
- Over 100 powerful commands for most demanding applications
- Motion program storage (up to 99 programs) in 25 kB non-volatile memory
- Advanced motion programming capabilities and complex digital and analog I/O functions
- User selectable displacement units
- User settable compensation for linear errors and backlash
- Optional full-featured front panel with dedicated displays for each axis, push-buttons for simple motion sequences and access to an elaborate menu that allows setup of the system without use of a computer.
- Optional handheld keypad for full access to MM3000 command set

1.3.2 Specifications

Function:

- Integrated motion controller and driver

Number of motion axes:

- 1 to 4, in any combination or order of stepper and DC motors

Trajectory type:

- Non-synchronized motion
- Multi-axis synchronized motion
- Trapezoidal velocity profile

Motion device compatibility:

- Family of motorized Newport motion devices, using either stepper or DC motors
- Custom motion devices (call for compatibility)

DC motor control:

- 12 bit DAC resolution
- 1 MHz maximum encoder input frequency
- Digital PID servo loop
- 0.256 ms digital servo cycle

Stepper motor control:

- 1.5 MHz maximum pulse rate
- Full, half, ministep (fullstep/10) and microstep (full/100) capability
- Open or closed loop operation

Computer interfaces:

- RS-232C
- IEEE488

Utility interfaces

- 8 bit digital inputs/outputs, user definable
- Analog to digital converter, 8 channels, 10 bits each, 0–9V
- Optional digital to analog converter, 4 channels, 8 bits each, 0–9V
- Remote motor off input (interlock)

User Memory

- 25 KB non-volatile program memory
- 5 KB non-volatile macro memory
- 512 byte command buffer

Operating modes:

- Local mode – stand-alone operation, executing motion from the front panel
- Remote mode – executing commands received over one of the computer interfaces or the optional handheld keypad
- Program execution mode – execution of a stored program

Optional display:

- 8 character alpha-numeric LED display for each axis
- Displays position, status, utility menus and setup screens

Dimensions:

- Without cooling fan: 5.28 (3U) H × 19 W × 16.50 D inches (132 × 475 × 412 mm)
- With cooling fan: 5.94 (4U) H × 19 W × 16.50 D inches (149 × 475 × 412 mm)

Power requirements:

- 115/230V ±10%, switchable, 50/60Hz
- 4A max.

Fuses

- AC line only

Line Voltage	**Fuse Type**
115V/230V	T4A/250V

Weight:

- 27 lb. max. (12 Kg max.)

Operating conditions:

- Temperature: 15°C to 40°C
- Humidity: 20% to 85% RH
- Rack Mounting Clearance: 0.5 in (top and bottom)

1.3.3 Description of Front Panel

The MM3000 is available with either a blank front panel or a front panel with dedicated displays for each axis. The front panel display version includes one display for each axis (8 characters) and push-buttons for simple manual motion sequences. Additionally, a menu allows the user to set up the motion system without a computer interface.

Front Panel Display

A general view of the front panel is shown in**Fig. 1.2**. There are three distinct areas: a power section, a display section with 5 push-buttons for each axis, and a menu section.

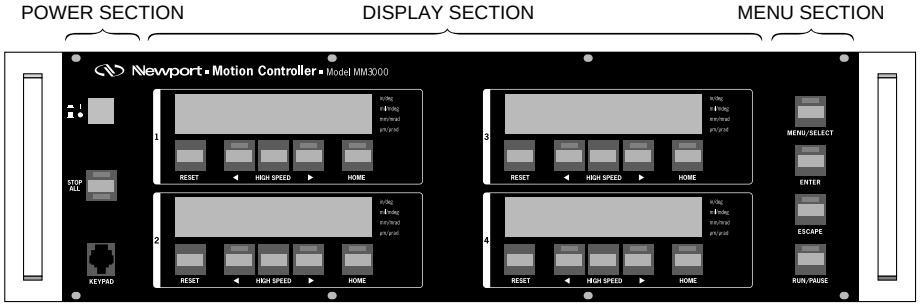


Fig. 1.2—MM3000 front panel with displays

Blank Front Panel

This version does not provide any displays or local operation via menus. It is equipped with the power section only. For description of the power section refer to the following section.

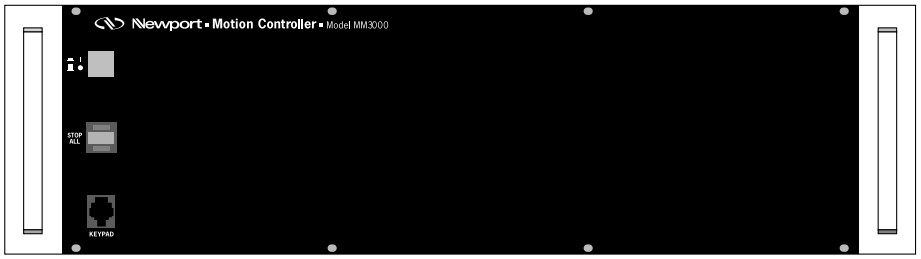
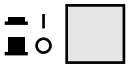


Fig. 1.3—MM3000 blank front panel

Description of Panel Sections

Power Section



The white push button type switch on the upper left corner is used to turn the controller power on (I) or off (O). The blank front panel version indicates the on state (I) with a green LED on the STOP ALL switch.

For safety reasons, the power to the motor can be controlled separately. This is done from the front panel with the STOP ALL button. For easier identification, the STOP ALL is the only one with a red push-button.

NOTE

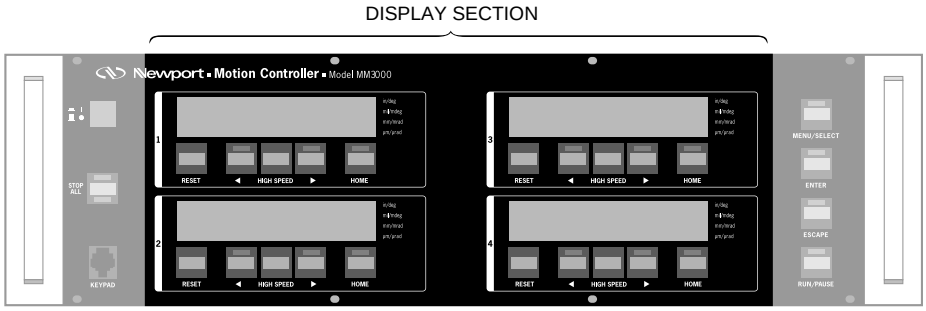
Activating this switch aborts all motion and disables motor power. All axes are affected.

The STOP ALL button has a red LED on the top that lights up momentarily when this button is pushed.

The green LED underneath the button serves as an indicator for power ON/OFF condition (blank front panel only).

An optional handheld keypad can be connected to the MM3000 through this receptacle . Refer to Section 6.2 for a detailed description of the keypad.

Display Section



Each of the four front panel displays is capable of displaying up to 8 alpha-numeric characters. Display 1 refers to the Axis 1 connector on the back of the controller, display 2 refers to Axis 2, and so on. The MM3000 alwayshas 4 displays no matter how many drivers are installed. Uninstalled drivers result in a blank display for the respective axis.

Located underneath each display you will find 5 push-buttons whose functions are described below.

Move in negative direction/jog.
To move a single step at a time, press this switch once.
To move continuously at low speed, press and hold the switch.
See Section 2 for setting of low speed rate.
The yellow LED above the switch indicates that the limit switch in the negative direction has been activated.

Move in positive direction/jog.
To move a single step at a time, press this switch once.
To move continuously at low speed, press and hold the switch.
See Section 2 for setting of low speed rate.
The yellow LED above the switch indicates that the limit switch in the positive direction has been activated.

HIGH SPEED

While this button is pressed in combination with either jog button, the motor moves with high speed. See Section 2 for setting of high speed rate.

HOME

Pressing the HOME switch will initiate a home search routine.
See Section 4 and OR command in Section 3 for a detailed description of the home search cycle.
The yellow LED above the switch lights up when a home search is in progress.

RESET

Pressing the RESET push-button will perform the following:

1. Reset the position display readout to zero
2. Set the present position as the floating home point (see OR command in the Command Section)
3. Set the present position as the reference for all subsequentabsolute positioning commands. See PA command in Section 3.
4. Shift the software limits setting such that the physical boundaries set previously are retained. See SL command in Section 3.

Menu Section

The MM3000 features 4 push-buttons to operate a menu system used to set parameters for each axis. Typical parameters that can be set are: type of stage, velocity, acceleration, PID values for DC motors, etc.

The 4 pushbuttons have the following functionality:

MENU/SELECT

Used to enter a menu and scroll through the menu selections.

See Section 2 for a deatiled description of the available menu items.

While in menu mode, the LEDS above each switch light up if activating the respective switch results in an action.

ENTER

Used to select the displayed parameter or setting.

ESCAPE

Used to escape from the present menu level to the previous level above without choosing the displayed parameter or setting.

Pressed during execution of a program, program execution is terminated.

RUN/PAUSE

Used to Run a stored program. Pressed during execution of a running program, the program is paused until this button is pushed again.
A flashing LED indicates that a program is paused.

1.3.4 Rear Panel Description

NOTE

For pin-outs see Appendix B.

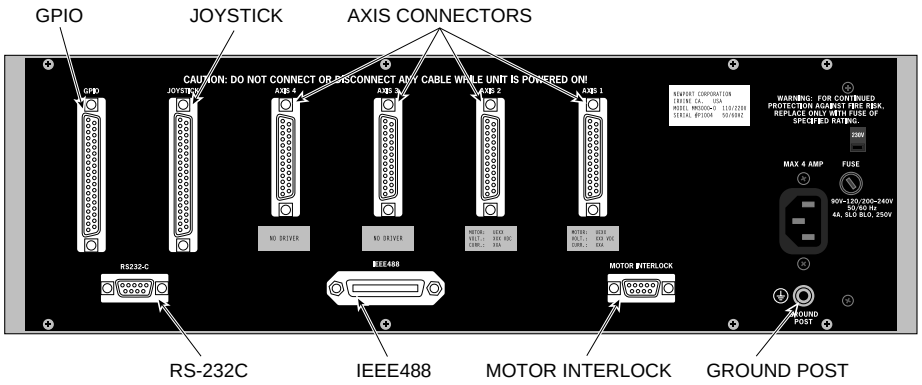


Fig. 1.4—Rear panel of the MM3000

Axis Connectors (AXIS 1–AXIS 4)

There are four 25 pin D-Sub connectors on the rear panel, one for each axis. An identification label that clearly specifies the model and the type of motor that the respective axis is configured for can be found underneath each connector. Unconfigured axes (i.e., there are no drivers installed) are marked with labels that read “NO DRIVER”.

CAUTION

Read the labels below each axis connector carefully and make sure that the specifications (motor type, voltage, current, etc.) match those of the motion devices you intend to connect. Serious damage could occur if a stage is connected to the wrong driver card.

GPIO Connector

This is a 37 pin D-Sub connector used for general purpose Input/Output signals. A variety of commands are available to control of these ports. See Section 3.

Joystick Connector

This 37 pin D-Sub connector is used to connect the optional joystick that allows control of up to 4 axes. The pinout of this connector is equivalent to the GPIO connector.

For a detailed description of the joystick see Section 6.1.

Motor Interlock Connector

The 9 pin D-Sub connector provides remote motor power interlock capability. One or more external switches can be wired to remotely inhibit the motor power in a way similar to the **STOP ALL** button on the front panel.

The controller is shipped with a mating 9 pin connector that provides the necessary wiring to enable proper operation without an external switch.

RS-232C Connector

The RS-232C interface to a host computer or terminal is made through this 9 pin D-Sub connector. The port has a three-line configuration using a software (XON/XOFF) handshake. The pinout enables the use of an off-the-shelf, pin-to-pin cable by providing internal jumpers that bypass hardware handshake signals, if needed.

IEEE488 Connector

This is a standard 24 pin connector to interface with a standard IEEE488 device.

Power Entry Module

The power entry section on the right side of the rear panel provides a standard IEC 320 inlet, a fuse holder, a voltage selector and a binding post to ground the controller if the main power supply wiring does not provide earth ground terminals.

CAUTION

Make sure that the voltage shown at the voltage selector matchesthe local line voltage before connecting the controller to power.

1.4 System Setup

This Section guides the user through the proper set-up of the motion control system.

If not already done, carefully unpack and visually inspect the controller and stages for any damage.

Place all components on a flat and clean surface.

CAUTION

No cables should be connected to the controller at this point!

First, the controller must be configured properly before stages can be connected.

1.4.1 Line Voltage Selection

CAUTION

Before applying AC power to the controller, check if the voltage specified on the power entry module (Fig. 1.5) on the rear of the controller corresponds to the local AC line voltage.

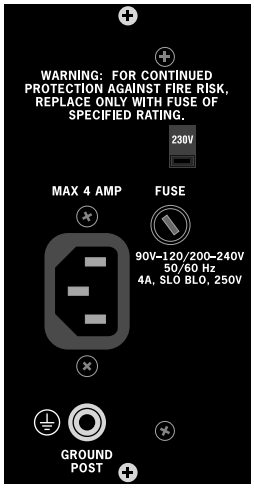


Fig. 1.5—Power Entry Section

If the indicated voltage as shown on the voltage selector does not match the local line voltage, change the voltage as described below.

NOTE

The controller can operate with 115VAC, ±10% or 230VAC, ±10% , at a frequency of 50/60Hz.

Changing the Line Voltage

1. If connected, remove the line cord from the power entry module.
2. Using a flat screwdriver, move the notch on the voltage selector as shown in **Fig. 1.6**. so that it shows your local AC line voltage.

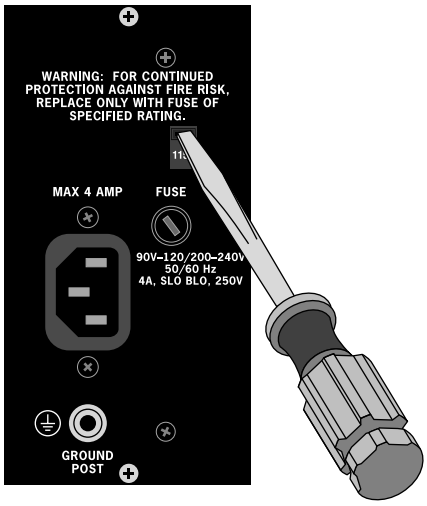


Fig. 1.6—Changing the Line Voltage

CAUTION

Make sure the main power switch on the front of the controller is turned off (O) before connecting the controller to the AC line.

1.4.2 First Power ON

Plug the AC line cord supplied with the MM3000 into the power entry module on the rear panel.

Plug the AC line cord into the AC wall-outlet.

Push in the POWER switch on the upper left side of the front panel .

Shortly after the power is switched on, the MM3000 with front panel display will perform a start-up sequence as described below. The blank front panel version indicates the ON state with a green LED below the STOP ALL switch.

NOTE

Any time you call for technical support, the firmware version is essential to trouble-shoot a problem. It is displayed every time the controller power is turned on. Users of the blank front panel can query the version with the VE command (see Section 3).

— Momentarily display: “Newport” and the installed Firmware Version

— Momentarily show the type of motor to be connected: “DC SERVO” or “STEPPER” for each axis that is configured. Displays for unconfigured axes show “NO MODLE”.

— For any axis that is configured to drive a stage but no stage is connected, the following message is displayed.

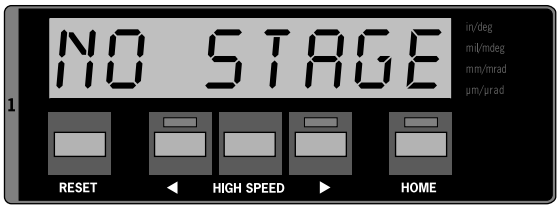


Fig. 1.7—Display after initial power up, no stage connected

For axes that are configured and have a stage connected, a display as shown below comes up.

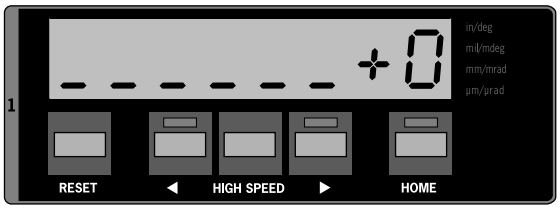


Fig. 1.8—Display after power up with stage connected

CAUTION

The “NO STAGE” message should be displayed if the system is set up the first time. If any of the displays shows “+0” (see Fig. 1.8), switch off the unit and disconnect all stages that are connected to the controller before proceeding.

NOTE

If any other message than shown above is displayed or the display does not light up at all, see Appendix for Troubleshooting Guide.

1.4.3 Verifying Default Devices

Before applying power to the motors, it is necessary to verify that the controller is configured for the actual motion devices it is supposed to drive.

The following procedure provides a quick way to set up generic parameters for each stage, e.g., PID parameters, velocities, accelerations. The values entered with the TYPE menu ensure operation of the motion system without having to “tune” the system. For optimal values for a specific application, it is necessary to determine the proper PID parameters, velocities, etc. using the procedure described in Section 4 and 5.

1. Press the MENU/SELECT key → Axis 1 is displayed. Press MENU/ SELECT to move to the axis that you would like to check. Press ENTER to pick the axis that you would like to check.

2. Press the MENU/SELECT key to move to the SEL TYPE menu. Press ENTER.

3. The displayed TYPE # should match the type for the motion device that is connected to the respective axis. A cross reference between motion devices and TYPE # can be found in Appendix C. In case there is a mismatch, proceed as follows:

   Press the MENU/SELECT key to select the TYPE # that the specific axis is configured for. Press ENTER.

4. Press ESCAPE repeatedly to get back to the "NO STAGE" display.

NOTE

Users of the blank front panel need to verify the controller configuration through one of the three interfaces (IEEE488, RS-232C or optional keypad) before proceeding to connect stages. Please refer to the appropriate Sections for instructions on the use of these interfaces.

NOTE

The TYPE# can also be set with the TY command. Refer to Section 3 for explanation of this command.

1.4.4 Connecting Motion Devices

If a standard motion control system was purchased, all necessary hardware for set-up is included.

The configuration of each axis is identified with a label located underneath each axis connector as shown:

```
MOTOR:   UEXX
VOLT.:   XXX VDC
CURR.:   XXA
```

CAUTION

Read the labels underneath each axis connector and make sure the specifications (motor type, voltage, current) match those for the motion devices you are connecting. Serious damage could occur if a stage is connected to the wrong driver card.

Carefully connect one end of the supplied cables to the stage and the other end to the appropriate axis connector on the rear of the controller. Secure both connectors with the locking thumb-screws.

1.5 Quick Start

This Section serves as a quick start for MM3000 with front panel display only.

Users of the MM3000 with blank front panel can skip to Section 3.

The following paragraphs guide you through a quick tour of the LOCAL motion commands.

CAUTION

It is strongly recommended that you read at least the System Setup Section before attempting to turn the controller or the motors on. Serious damage could occur if the system is not properly configured.

1.5.1 Motor On

After the controller is properly configured and the stages connected as described in the previous Section, the motors can be powered on.

Make sure that the motion devices are placed on a flat surface and their full travel is not obstructed.

CAUTION

Be prepared to quickly turn the motor power off by pressing the STOP ALL button or power switch if any abnormal operation is observed.

After the power switch is pushed in, the controller performs the start-up sequence as described in Section 1.4.2. The default state after start-up is motor power off. The display indicates disabled motor power with an underline preceding any numbers (see below).

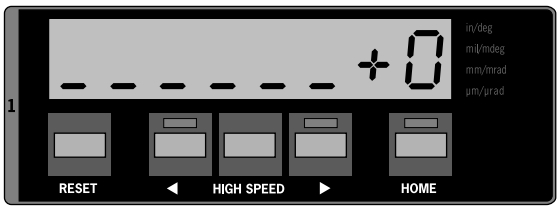


Fig. 1.9—Display showing motor off

To apply power to the motors, press either◄ or ► once for the respective axis. You may hear a small relay click inside the controller. The ON state of the motor is indicated with the missing underbar, as shown below.

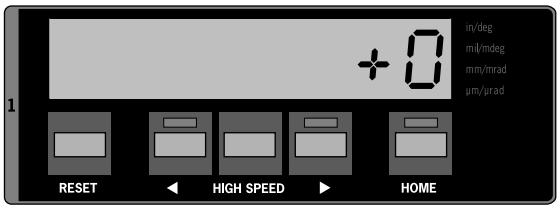


Fig. 1.10—Display showing motor on

1.5.2 Homing Motion Devices

It is good practice to always home the motion device before executing any motion. As described in detail in the **Motion Control Tutorial** Section, *homing* a motion device means executing a special routine that locates a predetermined position.

The MM3000 distinguishes between 3 different types of home:

1. The position defined by the location of a switch (mechanical, electro-optical, etc.) mounted on the stage.
2. The position defined by the location of a switch mounted on the stage plus the occurrence of an index pulse after the switch is triggered.
3. The position that corresponds to a position count of 0.

Home position type 3 is referred to as a floating home because it can always be defined by simply moving to a specific location and re-setting the position number to 0 (see also DH command in Section 3).

Before initiating a HOME search, the MM3000 must be set for the type of HOME search to be performed. The default type at initial power up is floating home (type 3).

See OR command in Section 3 for instructions to change the type of home search. Users of the display version can also use the menu (Section 2).

To initiate a home search, press the **HOME** key for the respective axis. After the axis starts the homing cycle, all function keys will be disabled and the display will indicate the progress. The LED above the **HOME** button will light up as long as home search is in progress. After the selected axis completes the search cycle, the LED is turned off.

1.5.3 First Jog

If ◄ is pressed, the selected axis will move slowly in the negative direction.

To move a single step at a time, press this switch once.

See Section 2 for setting of low speed rate.

If ► is pressed, the selected axis will move slowly in the positive direction.

To move a single step at a time, press this switch once.

See Section 2 for setting of low speed rate.

If the HIGH SPEED key between the jog keys ◄ or ► is pressed **simultaneously** with one of the above keys, the axis will jog fast in the selected direction. See Section 2 for setting of high speed rate.

At this point, you may experiment some more with the front panel to get familiar with the controller and the local motion modes.

NOTE

Remember that only motions inside the software travel limits are allowed (see SL command in Section 3). Any move outside these limits will be ignored.

Section 2
Modes of Operation

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Section 2 — Modes of Operation

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Section 2
Modes of Operation

2.1 Overview of Operating Modes

The MM3000 can be operated in two modes:

— Local Mode

— Remote Mode

Following is an overview of these two modes of operation.

LOCAL Mode

This mode is applicable only if your unit is equipped with the optional front panel display. If your MM3000 is equipped with the blank front panel, you may skip to the REMOTE Mode Section.

In LOCAL mode, the user has access to a sub-set of MM3000 motion commands. In this mode, the MM3000 is controlled by pressing the keys on the front panel. The displacement keys below each display allow manual control of simple motion sequences and the menu keys on the right side of the front panel provide access to a menu that enables the user to set up a motion system without use of IEEE488 or RS-232C interfaces. The diagram below illustrates the capabilities of the front panel display.

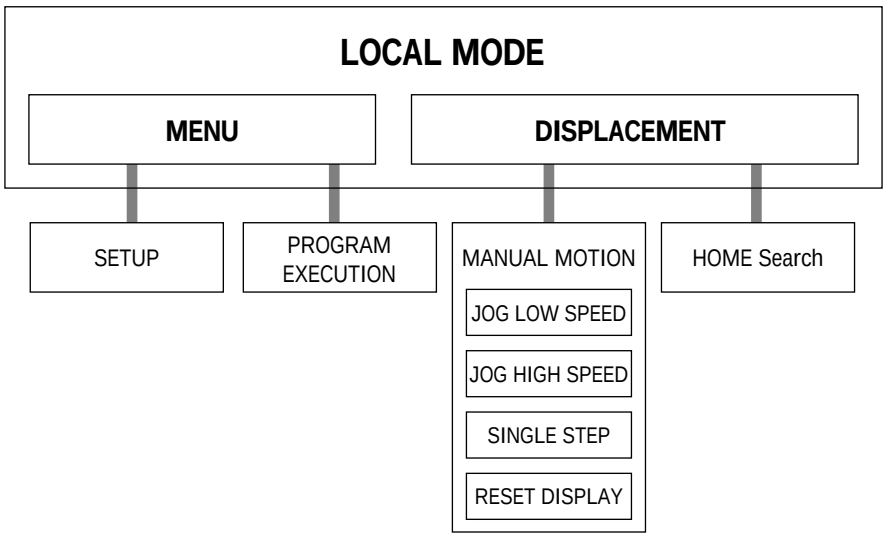


Fig. 2.1—LOCAL mode functions

MENU describes the 4 keys on the right side of the front panel. With these keys, the user can **setup** the general operation of the controller and **execute programs** that are stored in program memory.

DISPLACEMENT refers to simple manual motion using the 5 push-buttons below each display. When the **HOME** button is pushed, the controller executes a home search algorithm. The controller will exit this mode automatically on task completion.

Please see Section 1.3.3 for a detailed description of the displacement keys.

REMOTE Mode

In REMOTE mode, the controller can be placed into two different sub-modes. When placed in *COMMAND mode,* the MM3000 receives motion commands through one of its interfaces (RS-232C or IEEE488) using a computer or terminal. Additionally, an optional alphanumeric keypad with LCD display enables the user to access the full command set of the MM3000 without the use of a computer interface (see Section 6.2). The other sub-mode, called *PROGRAM EXECUTION mode,* desribes a state in which the controller executes up to 99 previously downloaded programs.

In either sub-mode, the MM3000 employs a set of over 100 commands. Please refer to Section 3 for a detailed description of the MM3000 command set.

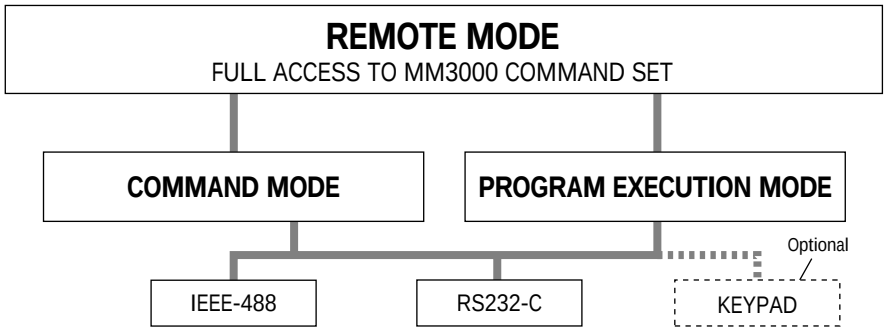


Fig. 2.2—REMOTE mode structure

2.2 Menu Options in LOCAL Mode

This Section provides a comprehensive explanation of the menu items available in LOCAL mode. Please remember that all menu items can also be accessed with remote commands (see Section 3). Typical parameters that can be set are: type of stage, velocity, acceleration, PID values for DC motors, etc.

2.2.1 Accessing the Menu

The menu can be accessed through the 4 menu keys on the right side of the front panel as shown in **Fig. 2.3**.

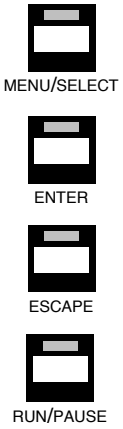


Fig. 2.3—Menu Keys

The 4 pushbuttons have the following functionality:

Used to enter a menu and scroll through the menu selections as shown in **Fig. 2.4**.

Used to accept the displayed parameter or menu item. Parameters are stored in memory.

Used to escape from the present menu level to the previous level without choosing the displayed parameter or menu item.

If the controller is executing a stored program, the ESCAPE button can be used to quit program execution.

Used to run a stored program. Pressed during the execution of a program, the program is paused until this button is pushed again.

A flashing yellow LED above the button indicates a paused program.

NOTE

All remote communication is ignored while the MM3000 is inthis mode.

Below you will find the menu structure.

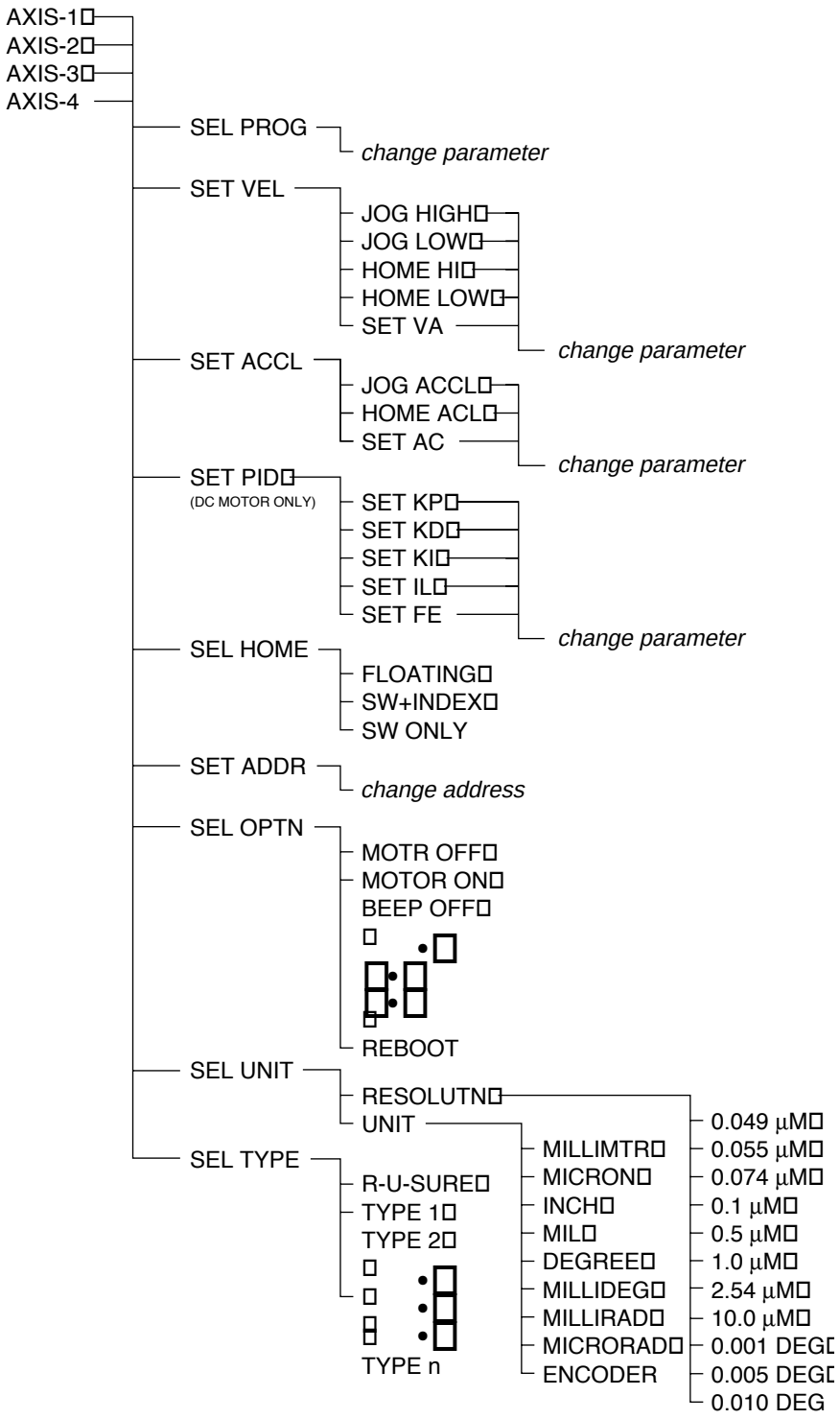
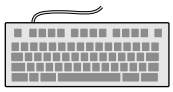


Fig. 2.4—Menu-tree

2.2.2 Description of Menu Items

AXIS #

To enter the menu, press **MENU/SELECT** key. **AXIS #** will be displayed. Repeatedly pressing the **MENU/SELECT** key advances to the desired axis. Press **ENTER** to access the menu for the chosen axis.



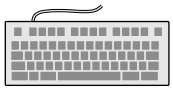
(INTEGER) preceding a command - select axis

example: 1TP / *tell position of axis 1*

SEL PROG

This menu item allows the user to select a previously stored program for execution. The chosen program will be executed when the **RUN/PAUSE** button is pushed.

Programs can be downloaded to the MM3000 through its standard interfaces (IEEE488 or RS-232CC) or with the optional handheld keypad. The MM3000 is capable of storing up to 99 different programs in its non-volatile program memory (25KB total, see EP command in Section 3).



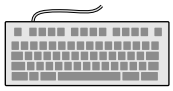
EX - execute program

SET VEL

This menu item makes it possible to change the velocities that are used in connection with the jog and home search buttons. The following sub-menus are available:

JOG HIGH

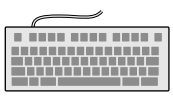
Sets the velocity of the stage when the **HIGH SPEED** button is pushed simultaneously with ▶ or ◀.



JH - set jog high velocity

JOG LOW

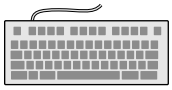
Sets the velocity of the stage when either ▶ or ◀ is pushed continuously.



JW - set jog low velocity

HOME HI

Sets the high velocity on the initial motion towards the home location. See Section 4.4.3 for details on the home search cycle.

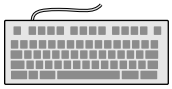


OH - set home high velocity

HOME LOW

Sets the low velocity for the final slow approach towards the home position.

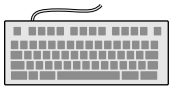
See Section 4.4.3 for details on the home search cycle.



OL - set home low velocity

SET VA

Sets the maximum velocity for the optional joystick and velocities for other move commands in remote mode unless otherwise specified with other velocity commands.



VA - set absolute velocity

SET ACCL

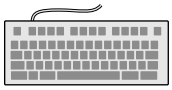
This menu item enables the user to change accelerations that are used in connection with ► or ◄ and home search.

The following sub-menus are available:

JOG ACCL

Sets the acceleration value used to accelerate (or decelerate) to the desired velocity when the jog buttons are used.

See Section 4.4.1 for details on the velocity profile.

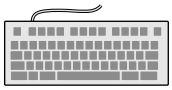


JA - set jog acceleration

HOME ACL

Sets the acceleration (and deceleration) value for the home search cycle.

See Section 4.4.3 for details on homing.



OA - set home search acceleration

SET AC

Sets the acceleration (or deceleration) for joystick operation and other move commands in remote mode unless the acceleration is specified in remote mode.

SET PID

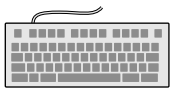
This menu allows the user to modify the digital PID filter for DC motors. All standard motion devices offered with the MM3000 have a set of conservative PID parameters stored in the controller's firmware. To change them, some knowledge of motion control loops is needed. Therefore, it is not recommended to modify the pre-set values before reading some general guidelines in the **Servo Tuning** Section. See also Section 4 for details on PID servo loops.

The recommended set of PID parameters for a specific stage can be found in Appendix C. They can also be programmed with the help of the **SEL TYPE** menu, which is the recommended method for first time users.

The following sub-menus are available:

SET KP

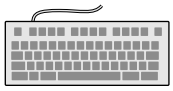
This parameter is the proportional gain factor of the digital PID filter.



KP - set proportional gain

SET KD

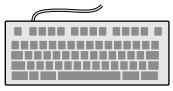
This parameter is the derivative gain factor of the digital PID filter.



KD - set derivative gain

SET KI

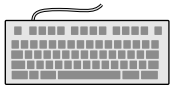
This parameter is the integral gain factor of the digital PID filter.



KI - set integral gain

SET IL

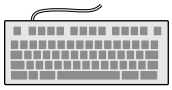
This parameter is the limit for the integrated value due to the integral gain factor of the digital PID filter multiplied with the following error.



IL - set integral gain

SET FE

This parameter represents the maximum following error, i.e., the difference between commanded and actual position. If at any time, the following error for a specific axis exceeds this value, the controller stops motion in progress and turns motor power off. Use good judgment when setting this parameter. A small value will cause premature fault and a large value will not protect the system from a real problem.



FE - set maximum following error

SEL HOME

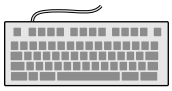
This menu allows the user to choose between 3 different type of homing. Please refer to Section 1.5.2 for a description of the home search types.

This menu only selects the type of homing, but does not initiate a home search. After the type selection has been made, exit the menu and push the HOME button for the respective axis or send the OR command.

The following sub-menus are available:

FLOATING

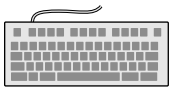
Floating home search means the controller returns the stage to 0 position count.



OM0 - Origin mode 0 (home 0)

SW+INDEX

SW+INDEX home search means the controller returns the stage to a position determined by a home switch in connection with an index pulse.

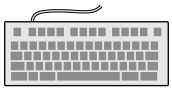


OM1 - Origin mode 1 (home 1)

SW ONLY

SW ONLY home search means the controller returns the stage to a position determined by a home switch only. No index pulse is required.

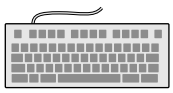
If this mode is chosen for DC motors, a jumper has to be set inside the controller. Refer to the Appendix I for instructions.



OM2 - Origin mode 2 (home2)

SET ADR

Sets the address for IEEE488 and RS-232C daisy chain mode (see Appendix E). The setting will be stored in non-volatile memory.



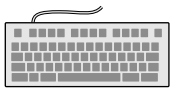
AD - set address

SEL OPTN

This provides access to a set of sub-menus that allow the user to change numerous options, e.g., motor power, beep on/off, etc. Some of the items available depend whether the axis is a DC or stepper.

MOTR OFF

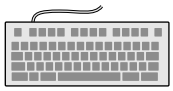
MOTR OFF removes power from the motor for the respective axis. To quickly turn motor power off to all axes, press the STOP ALL button.



MF - motor off (axis 1)

MOTOR ON

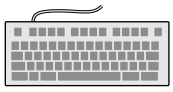
MOTOR ON applies power to the motor. Note that any move command automatically applies power to the motor.



MO - motor on (axis 1)

BEEP OFF

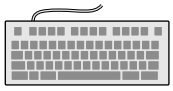
The MM3000 provides acoustic feed-back for the push-buttons and certain occurences. With this menu item, the beeper can be disabled.



FS:40 - disable beep

BEEP ON

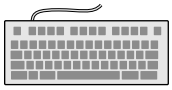
The MM3000 provides acoustic feed-back for the push-buttons and certain occurences. With this menu item, the beeper can be enabled.



FS&BF - enable beep

JOYSTK#

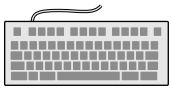
JOYSTK# assigns a specific controller axis to a joystick axis. Refer to Section 6.1 for details.



1JY1 - assign joystick axis 1 to controller axis 1

LOOP ON

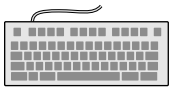
This item is available for stepper axes only. LOOP ON enables closed loop operation of stepper motors (see CL command for details).



CL ON - closed loop on (axis 1)

LOOP OFF

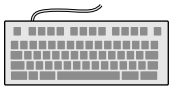
This item is available for stepper axes only. LOOP OFF disables closed loop operation of stepper motors.



CL OFF - closed loop off (axis 1)

BASE 100

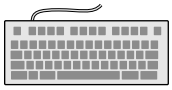
This item is available for stepper axes only. BASE 100 sets the start and stop speed of stepper motors to 100 steps/sec (see VB command).



VB - set base velocity

BASE 4000

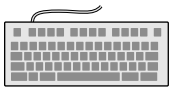
This item is available for stepper axes only. BASE 4000 sets the start and stop speed of stepper motors to 4000 steps/sec (see VB command).



VB - set base velocity

RATIO 1

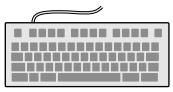
This item is available for stepper axes only. RATIO 1 sets the encoder/pulse ratio to 1. See ER command for details.



ER - set encoder ratio

RATIO 10

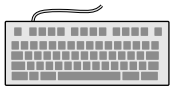
This item is available for stepper axes only. RATIO 10 sets the encoder/pulse ratio to 10. See ER command for details.



ER - set encoder ratio

STEP CNT

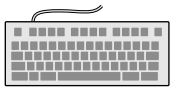
This item is available for stepper axes only. STEP CNT places the axis in step count mode. All positioning and position reporting is in step counts. See FM command for details.



FM - format motion

ENCR CNT

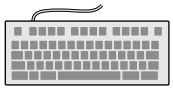
This item is available for stepper axes only. ENCR CNT places the axis in encoder count mode. All positioning and position reporting is in encoder counts. See FM command for details.



FM - format motion

SRQ ON

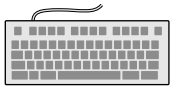
SRQ ON enables SRQ for IEEE488 interface.



FI - format interrupt

SRQ OFF

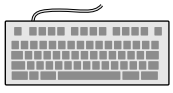
SRQ OFF disables SRQ for IEEE488 interface.



FI 00 - format interrupt (SRQ OFF)

SOFT ON

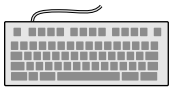
This menu enables the soft travel limits. See SL command for details.



FM - format motion

SOFT OFF

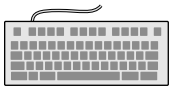
This menu disables the soft travel limits. See SL command for details.



FM - format motion

DAISY ON

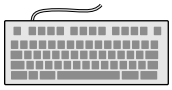
This menu enables daisy chain mode for the RS-232C interface. See Appendix E for details.



DC 1 - Daisy chain mode on

DAISY OFF

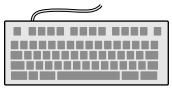
This menu disables daisy chain mode for the RS-232C interface. See Appendix E for details.



DC 0 - Daisy chain mode off

REBOOT

This menu reboots the controller. Any commands in the command buffer are erased at this point. Rebooting is equivalent to a power on/off cycle of the controller.



RS - reboot controller

PURGE MEM

This menu erases the contents of the non-volatile memory. See XX command for details. Use this menu only in case the memory gets corrupted and causes faulty operation.

SEL UNIT

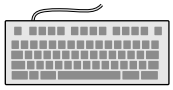
The MM3000 is capable of displaying position in different measurement units (e.g., microns). The type of units to be displayed is indicated on the right side of the 8 digit LED field.

Additionally, a number of commands support positioning in units. See UA, UV, UR, UP, US, UU and UW commands for details.

It is necessary to first determine the stage resolution before a measurement unit can be chosen. See US command for details.

RESOLUTN

This menu allows the user to select a range of predefined encoder resolutions for a specific stage.



US - unit resolution

UNIT

After the resolution of the stage has been entered with the **RESOLUTN** menu, the user can choose between selected measurement units for either rotary or linear motion.

The selecton is as follows:

MILLIMTR
Millimeter (10^{-3} m)

MICRON
Micrometer (10^{-6} m).

INCH
Inch

MIL
Milli-inch (10^{-3} inch)

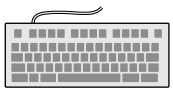
DEG
Degree

MILLIDEG
Milli-degree (10^{-3} degree)

MILLIRAD
Milli-radiant (10^{-3} radiant)

MICRORAD
Micro-radiant (10^{-6} radiant)

ENCODER
Encoder counts



UU - units

SEL TYPE

This menu item allows the user to configure the MM3000 with all necessary parameters (e.g., PID, velocities, accelerations, etc., see TY command in Section 3) without individually entering each value. All parameters are generic. For optimal parameters it is necessary to “tune” the system for a specific application (see Sections 4 and 5). For a cross reference between TYPE# and motion devices, see Appendix C.

Section 3
Remote Mode

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Section 3 — Remote Mode

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Section 3
Remote Mode

3.1 Programming Modes

The MM3000 is a command driven system. Commands are a series of two letter ASCII characters with a numeric parameter denoting the axis number to be addressed. To communicate with the MM3000, a host terminal has to transfer ASCII character commands according to the respective communication protocol (see Section 3.2 for IEEE or RS232 interfaces).

As briefly mentioned in Section 2, the MM3000 distinguishes between two different programming modes:

Command Mode

In this mode, the MM3000 provides a 512-byte command input buffer enabling the host terminal (e.g, PC) to download a series of commands and then proceed to other tasks while the MM3000 processes the commands.

As command characters arrive from the host terminal, they are placed into the command buffer. When a carriage-return (ASCII 13 decimal) terminator is received, the command is interpreted. If the command is valid and its parameter is within the specified range, it will be executed. If the command contains an error, it will not be executed and a corresponding error message will be stored in the output buffer.

NOTE

The MM3000 power up state is command mode.

An example of a typical command sequence is shown below:

Example 1:

1PA+3000	*move axis 1 to absolute position 3000*
1WS	*wait for axis 1 to stop*
2PR-1000	*move axis 2 to relative position 1000*

Assuming that axis 1 and 2 are configured, example 1 instructs the MM3000 to move axis 1 to absolute position +3000, wait for it to stop, and then move axis 2 motor to –1000 counts relative to its previous position.

Note that a command prefix (1 through 4) identifies the axis that should execute a command. Commands received without an axis prefix default to the last prefix (axis) issued. If a command is referenced to a non-existing axis, an error is generated. See Section 3.4 for further datails on the command syntax.

Also note the necessity to explicitly instruct the MM3000 with the WS (Wait for Stop) command to wait for axis 1 motion to stop. This is necessary because the MM3000 executes commands contiguously as long as there are commands in the buffer unless a command is fetched from the buffer that instructs to wait. Executing a move does not automatically suspend command execution until the move is complete. If the WS command were not issued in example 1, the controller would start the second move immediately after the first move begins and simultaneously move axis 1 and axis 2.

NOTE

Unless instructed otherwise, the MM3000 executes commands in the order received without waiting for completion of previous commands.

Remember, commands must be terminated with a carriage-return (ASCII 13 decimal). Until a terminator is received, characters are simply kept in contiguous buffer space without evaluation.

Example 2:

```
1PA+3000;1WS;2PR-1000
```

Example #1 and #2 perform the same operations. In example #2 however, semicolons are used in place of carriage-returns as command delimiters, keeping the MM3000 from interpreting any commands on that line until the carriage-return terminator is received at the very end of the string.

Program Execution Mode

The MM3000 also implements an internal program execution mode that enables the user to store up to 99 programs in a 25 kB non-volatile memory. Additionally, 5kB of memory can be dedicated to program macros (see CM command).

Even while executing stored programs, the MM3000 maintains open communication channels so that the host terminal can continue to direct the MM3000 to report any desired status, and even execute other motion commands.

Let's illustrate program execution mode using the previous example:

Example 3:

```
EP                      | invoke program entry mode
1PA+3000                | enter program
1WS
2PR-1000
%                       | exit program entry mode
CP                      | compile stored program
COMPILATION COMPLETED   | response from MM3000
END                     | response from MM3000
EX1                     | execute compiled program # 1
```

As shown above, the sequence of commands has to be downloaded into the MM3000 program memory without inadvertently executing them. To facilitate this, the system provides the EP (Enter Program) command; characters received thereafter are redirected to program memory. Commands syntax and parameters are not evaluated (even after the carriage-return). Instead, they are treated as a series of characters to be stored in contiguous memory.

/QP separates multiple programs. Program numbers are incremented by 1 with every /QP issued. Up to 99 programs can be created this way and executed independently.

The MM3000 continues to store commands in memory until it receives the % character followed by a carriage return, which instructs to exit program entry mode and return to command mode.

The CP command causes the MM3000 to evaluate the stored programs (source code) for incorrect syntax and parameters usage. If the downloaded commands contain errors, the compiler responds with the error message "COMPILATION ABORTED" plus the listing of all the lines which contained an error. The last transmission is the word END to signal the end of data.

Assuming there are no errors, the execute program command (i.e.,EX) can be issued to execute programs. If the program has not been compiled prior to issuing the EX command, EX will automatically compile *and* execute if no errors exist. Note, while the program is running, certain commands can still be transmitted and executed, e.g., 2TP (tell position), 1VA5000 (absolute velocity), or 3PR1000 (position relative).

Summary

Command Mode

1. Commands are received and temporarily stored in a 512 byte command queue until they are fetched and executed.
2. A carriage-return (ASCII 13 decimal) terminates a command and causes the MM3000 to begin processing.
3. Multiple commands (up to 80 characters) may exist on a single line if delimited by semicolons, e.g., 1PR+1000;1WS;2PR-1000;2WS
4. Commands missing axis prefixes default to the last reference, e.g., 1PA+1000;WS (the WS command defaults to axis 1)
5. The WS or WA command causes the MM3000 to wait until the target position is reached before processing the next command.

Program Execution Mode

1. The EP command invokes program entry mode which transfers incoming characters to program memory.
2. /QP starts a new program (old program number+ 1)
3. The % command causes the system to exit program entry mode.
4. A stored program must be successfully compiled with theCP command before it can be executed. Alternatively, theEX command compiles **and** executes programs if no errors exist.
5. New real-time commands are accepted and executed even while running a program.
6. The WS or WA command causes the MM3000 to wait until the target position is reached before processing the next command.

3.2 Remote Interfaces

In this manual, *Remote Interface* refers to the two communication interfaces that the controller can use to communicate with a computer or a terminal via commands in ASCII format. It is not called a *Computer Interface* since any device capable of sending ASCII characters can be interfaced with the controller.

The Remote Interface should not be confused with the General Purpose Input/Output (analog and digital I/Os, a.k.a. GPIO).

3.2.1 RS-232C Interface

Hardware Configuration

The serial (RS-232C) communication interface on the MM3000 is accessed through the 9 pin Sub-D connector located on the rear panel. The pinout is designed to interface directly with an IBM PC or compatible computer, using a straight through cable.

Appendix **B** shows the pinout of the RS-232C connector and different cable types that may be used to interface to a computer.

Communication Protocol

The RS-232C interface must be properly configured on both devices communicating. A correct setting is one that matches **all** parameters (baud rate, number of data bits, number of stop bits, parity type and handshake type) for both devices.

The MM3000 RS-232C configuration is fixed at **8 data bits, no parity, and 1 stop bit**.

The baud rate can be set with the SR command (see Command Section).

To prevent buffer overflow when data is transfered to the MM3000 input buffer (512 Byte), an **XON/XOFF** protocol is implemented. The host terminal can control transmission of characters from the MM3000 by sending XON/XOFF control commands. Before sending any further characters, the MM3000 will wait for an XON (ASCII 17 decimal) if the host terminal previously sent an XOFF (ASCII 19 decimal) to stop transmission. If no XON is received within 0.5 seconds, the MM3000 will time-out.

As soon as its 512 byte command buffer is full, the MM3000 sends an XOFF. Then, as space becomes available as the MM3000 reads and executes commands in its buffer, it will send an XON to the host terminal.

See FO command to enable or disable XON/XOFF handshaking.

Daisy-Chaining Multiple MM3000's

The MM3000 provides support for daisy-chained RS-232C serial communication. Up to 32 MM3000's may be controlled through one single RS-232C host serial port. Without this feature, every MM3000 would require a separate serial port.

When an MM3000 receives a character from the host terminal in daisy-chained RS-232C mode, it always sends that character to the next MM3000 in the chain. At the end of the chain, the last MM3000 will send the command back to the host computer. Each string sent to the host terminal by the MM3000 has an axis prefix number followed by a ">".

NOTE

To guarantee only one "talker" in the chain at a time, responses from each MM3000 should be synchronized by disabling RS-232C error message transmission using the FO command.
For a more detailed explanation of the FO command see Section 3.6.

Please refer to Appendix E for details on the daisy chain mode.

3.2.2 IEEE488 Interface

Hardware Configuration

A typical IEEE488 setup consists of a controller (host terminal) and several devices connected to the bus. All devices are connected in parallel to the data lines, data management and sychronization lines. As a result of this type of connection, each device on the bus must have an address so that the controller can selectively communicate with it.

The address can be set through the optional front panel display or with the AD command. Alternatively, the required address can be set using DIP switches inside the MM3000. See Appendix F for instructions. Whichever address set last overrides the previous address and is stored in non-volatile memory. It remains valid during all subsequent power on/off cycles.

See Section 2.2 for setting the address using the front panel menu.

Communication Protocol

The IEEE488 interface is implemented on the MM3000 somewhat differently from a typical instrument because the standard IEEE488.2 command set and command format are inadequate for a complex motion controller. Since the MM3000 has its own language and command set, the IEEE488 interface is used only as a communication port. The extended protocol is not supported.

The MM3000 has an ASCII command set and also outputs system status in ASCII format. It features a 512 byte command input buffer. If the buffer fills up, the MM 3000 will not allow further communication until space becomes available to accept new characters.

To send a command to the MM3000, use the command specifc to your IEEE488 terminal (e.g., output(ASCII)).

If the host terminal asks the MM3000 for a response (e.g., input(ASCII)) and no response is obtained within 0.5s, the MM3000 will time-out. Time-out can be disabled with the FO command (see Command Section).

Use of SRQ Line

The MM3000 can be programmed to generate an IEEE488 service request on occurrence of certain events. These events are:

- Motion complete on any of the 4 axes, or Command errors and messages

  The FI command can be used to select the event that should cause this type of service request. See Command Section for further information.

- Execution of an RQ command

  Sometimes, it may be more efficient and possibly desirable to generate a service request when a sequence of commands is completed, rather than when each individual motion is finished. The RQ command can be used for this task. Here, a service request is generated only when an RQ command is executed. To use the RQ command for service request generation, FI interrupts have to be disabled (see FI command in Section 3.6).

  The following example illustrates the use of the RQ command:

  1PR100;WS;2PR100;3PR100;WS;RQ

  In the above example, the SRQ line is asserted only after execution of the sequence preceding the RQ command is finished.

Serial Poll

When the IEEE488 controller senses a service request on the bus, it creates an interrupt to the application program. The application program must contain a service routine for this interrupt. First, the program must determine which device on the bus generated the service request. This is usually achieved with a function called serial poll. The exact syntax for the serial poll command depends on the IEEE488 controller.

Using that interrupt service routine, a serial poll command can be issued to each device (e.g., MM3000). The device polled at each instance will respond with a status byte. Bit 6 of the status byte indicates whether a specific device generated the service request. Bits 0 through bit 5 contain additional system status information which indicate the reason why the service request was generated.

Please refer to TS command for a description of the status byte.

3.3 Software Utilities

In order to communicate with the controller, the user must have a terminal or a computer capable of communicating through RS-232C or IEEE488. One approach is to use a computer with communications software that can emulate a terminal. An even easier solution is to use one of the software utilities included with the controller.

The MM3000 is supplied with three utility software programs. These programs are designed to work on a DOS based computer. Their main purpose is to help the user setup the motion control system, exercise controller capabilities and to calibrate and *tune* the system for best performance.

Though any type of motion program can be created using these utilities, many users will prefer to use their own environment that better fits their application.

A complete description of the programs and their features can be found in the **EZ Motion Control Utilities User Manual**

Start-Up Program

This is an intelligent terminal emulator that was written specifically for the MM3000. The software works very closely with the controller. It knows the language and the conventions of the controller. It knows what to ask and what to expect back. It is an extension of the controller, a motion control environment. The status of the controller and the motion devices can be continuously monitored. Complex programs can be created, tested, saved and recalled.

Profile

Its purpose is to facilitate tuning of the PID servo loops easily and intuitively. It automatically controls the MM3000, reads and calculates all important dynamic motion parameters and plots graphically. This utility is designed to be used primarily by more experienced users, with some knowledge of servo systems. There is always some risk involved in changing the servo loop parameters in a manner that could render the motion device inoperative, or even damage it. Before using this program, read the **Servo Tuning** and, if needed, the **Motion Control Tutorial** chapter.

EZ232

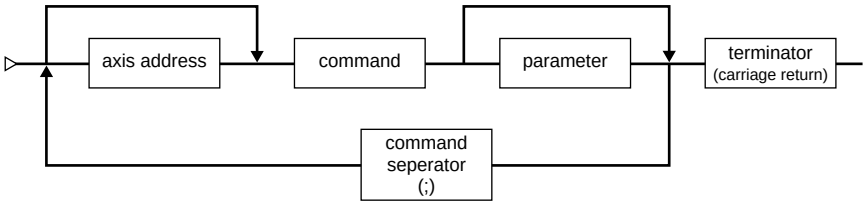
This is a general purpose RS232-C serial interface communications program. This utility will allow users that are already familiar with the MM3000 command syntax to send commands and read responses from the controller.

3.4 Command Syntax

As mentioned previously, the MM3000 utilizes an ASCII command set and also outputs system status in ASCII format.

MM3000 commands consist of an axis designator followed by two letter mnemonic characters, (mostly) followed by a numerical parameter and terminated by a carriage return. Commands may be either upper or lower case characters and with or without spaces anywhere in the command line. For example, 3Pa +100 is a valid command. A command sent without an axis number defaults to the last axis addressed. In the command sequence 2PA+100;WS10;TP, the WS and TP commands default to axis 2.

The diagram below illustrates the command syntax.



NOTE

An MM3000 command (or a sequence of commands) has to be terminated with a carriage return character. However, responses from the MM3000 are always terminated by a carriage return/line feed combination. This setting may not be changed. If the IEEE interface is used, the IEEE controller has to be configured to terminate the input (read) function when it senses the line feed character.

Summary of Command Syntax

Command Format

The general format of a command is a two character mnemonic (**AA**). Both upper and lower case are accepted. Depending on the command, it could also have optional or required preceding (**xx**) and/or following (**nn**) parameters.

Blank Spaces

Blank spaces are allowed and ignored in any position, including inside a numerical value. For the clarity of the program and memory saving considerations, use blank spaces with restraint. The following two commands are equivalent

2P A1 00 0

2PA1000

but the first example is very confusing and uses more than twice the memory

Command Line

Commands are executed line by line. A line can consist of one or a number of commands. The controller will interpret the commands in the order they are received and execute them sequentially. This means that commands issued on the same line are executed significantly closer to each other than if they would be issued on separate lines. The maximum number of characters allowed on a command line is 80.

Separator

Commands issued on the same line must be separated by semicolons (;).

Terminator

Each command line must end with a line terminator, i.e., carriage return.

3.5 Command Summary

The MM3000 controller understands more than 100 commands. The following two tables list all of them, sorted first by category and then alphabetically. The tables also show the operating modes in which each command can be used. The acronyms used in the tables have the following meaning:

IMM	IMMediate mode	controller is idle and the commands will be executed immediately.
PGM	ProGraM mode	controller does not execute but stores all commands as part of a program. EP activates this mode and % exits it.
MIP	Motion In Progress	controller executes a motion on the specified axis.

3.5.1 Command List by Category

Cmd.	Description	IMM	PGM	MIP	Page
Motion					
AB	Abort motion	■	■	■	3.17
AC	Set acceleration	■	■	□	3.18
JA	Set jog acceleration	■	■	■	3.52
JH	Set jog high speed	■	■	■	3.53
JW	Set jog low speed	■	■	■	3.55
ML	Move to travel limit	■	■	■	3.63
MV	Move indefinitely	■	■	■	3.66
MZ	Move to index pulse	■	■	■	3.67
OA	Set origin search acceleration	■	■	■	3.68
OH	Set origin search high velocity	■	■	■	3.69
OL	Set origin search low velocity	■	■	■	3.70
OR	Perform origin search	■	■	□	3.72
PA	Position absolute	■	■	■	3.74
PR	Position relative	■	■	■	3.77
SD	Speed divide	■	■	■	3.89
ST	Stop motion	■	■	■	3.93
VA	Set velocity value	■	■	■	3.121
VB	Set base velocity: start/stop velocity	■	■	■	3.122
VR	Increment/decrement present velocity	■	■	■	3.124
VS	Sample-time velocity mode	■	■	■	3.125
Motion in Units					
UA	Set unit acceleration	■	■	□	3.110
UP	Move to absolute unit position	■	■	■	3.113
UR	Units position relative	■	■	■	3.115
US	Define resolution	■	■	□	3.117
UU	Select positioning unit	■	■	□	3.118
UV	Set unit velocity	■	■	■	3.119

Cmd.	Description	IMM	PGM	MIP	Page
Motion Related					
BA	Enable backlash compensation	■	■	□	3.20
CL	Enable closed loop stepper	■	■	□	3.24
CO	Enable linear compensation	■	■	□	3.27
DH	Define home	■	■	■	3.31
DS	Derivative sampling interval	■	■	■	3.34
FE	Set following error threshold	■	■	■	3.40
IL	Set integration limit	■	■	■	3.51
JY	Enable joystick control	■	■	■	3.56
KD	Set PID Derivative constant	■	■	■	3.57
KI	Set PID Integration constant	■	■	■	3.58
KP	Set PID Proportional constant	■	■	■	3.59
MF	Turn motor power off	■	■	■	3.62
MO	Turn motor power on	■	■	■	3.64
OV	Set overshoot value for home search	■	■	■	3.73
SE	Simultaneous command execution	■	■	■	3.90
SL	Set soft (travel) limits	■	■	■	3.91
SY	Set axes for simultaneous execution	■	■	■	3.95
TY	Select stage type	■	■	□	3.109
UF	Update PID filters	■	■	■	3.112
Programming					
CM	Create macro	■	□	■	3.26
CP	Compile program	■	□	□	3.28
EM	Execute macro	■	■	□	3.36
EP	Enter program mode	■	□	□	3.37
EX	Execute program	■	□	□	3.39
IE	Initialize time interval execution mode	■	■	■	3.49
LM	List all macro definitions	■	■	■	3.60
LP	List stored program	■	□	■	3.61
PE	Power-on execution	■	□	□	3.76
QP	Quit program execution mode	■	□	□	3.79
/QP	Program delimiter	□	■	□	3.80
RM	Reset all macro definitions	■	■	■	3.84
RQ	Generate interrupt	■	■	■	3.86
SV	Set variable value	■	■	■	3.94
%	Quit program entry mode	■	□	□	3.134
‘	Program line comments	□	■	□	3.135
Reporting					
DA	Tell desired acceleration	■	■	■	3.29
DP	Tell desired position	■	■	■	3.33
DV	Tell desired velocity	■	■	■	3.35
MS	Tell motor status	■	■	■	3.65
RA	Read analog channel	■	■	■	3.81
RB	Read I/O bits	■	■	■	3.82
RC	Report module configuration	■	■	■	3.83
TB	Tell error buffer contents	■	■	■	3.96
TE	Tell error code	■	■	□	3.97
TF	Tell filters (PID)	■	■	■	3.98
TL	Tell soft limits and following error	■	■	■	3.100
TM	Tell memory usage	■	■	■	3.101
TP	Tell actual position	■	■	■	3.102
TPE	Tell positon in encoder units	■	■	■	3.103
TPI	Tell position in motor step units	■	■	■	3.104
TR	Initialize motion tracing mode	■	■	■	3.105
TS	Tell status	■	■	■	3.106
TT	Tell motion trace data	■	■	□	3.107
TV	Tell velocity	■	■	■	3.108
VE	Tell firmware version	■	■	■	3.123

Cmd.	Description	IMM	PGM	MIP	Page
Sequence					
DL	Define label	□	■	□	3.32
IF/THEN	IF condition THEN goto label	□	■	■	3.50
JL	Jump to label	□	■	■	3.54
RP	Repeat previous command	■	■	■	3.85
UW	Wait for position crossing in units	■	■	□	3.120
WA	Wait for all axes to stop	■	■	■	3.126
WB	Wait bit level, then execute	■	■	■	3.127
WHILE/WEND					
	WHILE bit(s) high/low ...WEND	■	■	■	3.129
WP	Wait for position, then execute	■	■	■	3.130
WS	Wait for stop, then execute	■	■	■	3.131
WT	Wait time, then execute next command	■	■	■	3.132
Miscellaneous					
AD	Set address	■	■	■	3.19
BI	Define input bits	■	■	■	3.21
BO	Define output bits	■	■	■	3.22
CB	Clear bits	■	■	■	3.23
DC	Enable/disable daisy-chaining	■	■	■	3.30
ER	Set encoder ratio	■	■	□	3.38
FI	Format interrupt	■	■	■	3.41
FM	Format motion	■	■	■	3.43
FO	Format output	■	■	■	3.45
FS	Format system	■	■	■	3.47
OM	Set home search type	■	■	■	3.71
RS	Reboot system	■	■	■	3.87
SB	Set bits high	■	■	■	3.88
SR	Select baud rate	■	■	■	3.92
TG	Toggle bits	■	■	■	3.99
WD	Write value to D/A channel	■	■	■	3.128
XX	Purge memory	■	□	□	3.133
#	Emergency stop	■	□	■	3.136

3.5.2 Command List - Alphabetical

Cmd.	Description	IMM	PGM	MIP	Page
AB	Abort motion	■	■	■	3.17
AC	Set acceleration	■	■	□	3.18
AD	Set address	■	■	■	3.19
BA	Enable backlash compensation	■	■	□	3.20
BI	Define input bits	■	■	■	3.21
BO	Define output bits	■	■	■	3.22
CB	Clear bits	■	■	■	3.23
CL	Enable closed loop stepper	■	■	□	3.24
CM	Create macro	■	□	■	3.26
CO	Enable linear compensation	■	■	□	3.27
CP	Compile program	■	□	□	3.28
DA	Tell desired acceleration	■	■	■	3.29
DC	Enable/Disable daisy-chaining	■	■	■	3.30
DH	Define home	■	■	■	3.31
DL	Define label	□	■	□	3.32
DP	Tell desired position	■	■	■	3.33
DS	Derivative sampling interval	■	■	■	3.34
DV	Tell desired velocity	■	■	■	3.35
EM	Execute macro	■	■	□	3.36
EP	Enter program mode	■	□	□	3.37
ER	Set encoder ratio	■	■	□	3.38

Cmd.	Description	IMM	PGM	MIP	Page
EX	Execute program execution	■	□	□	3.39
FE	Set following error threshold	■	■	■	3.40
FI	Format interrupt	■	■	■	3.41
FM	Format motion	■	■	■	3.43
FO	Format output following error	■	■	■	3.45
FS	Format system	■	■	■	3.47
IE	Initialize time interval execution mode	■	■	■	3.49
IF/THEN	IF bit(s) high/low THEN goto label	□	■	■	3.50
IL	Set integration limit	■	■	■	3.51
JA	Set jog acceleration	■	■	■	3.52
JH	Set jog high speed	■	■	■	3.53
JL	Jump to label	□	■	■	3.54
JW	Set jog low speed	■	■	■	3.55
JY	Enable joystick control	■	■	■	3.56
KD	Set PID Derivative constant	■	■	■	3.57
KI	Set PID Integration constant	■	■	■	3.58
KP	Set PID Proportional constant	■	■	■	3.59
LM	List all macro definitions	■	■	■	3.60
LP	List stored program	■	□	■	3.61
MF	Turn motor power off	■	■	■	3.62
ML	Move to travel limit	■	■	■	3.63
MO	Turn motor power on	■	■	■	3.64
MS	Tell motor status	■	■	■	3.65
MV	Move indefinitely until stopped	■	■	■	3.66
MZ	Move to top zero (marker) pulse	■	■	■	3.67
OA	Set home search acceleration	■	■	■	3.68
OH	Set home search high velocity	■	■	■	3.69
OL	Set home search low velocity	■	■	■	3.70
OM	Set home search type	■	■	■	3.71
OR	Perform origin search origin search	■	■	□	3.72
OV	Set overshoot value for home search	■	■	■	3.73
PA	Position absolute	■	■	■	3.74
PE	Power-on execution	■	□	□	3.76
PR	Position relativepresent velocity	■	■	■	3.77
QP	Quit program execution mode	■	□	□	3.79
/QP	Program delimiter	□	■	□	3.80
RA	Read analog channel	■	■	■	3.81
RB	Read I/O bits	■	■	■	3.82
RC	Report module resolution	■	■	■	3.83
RM	Reset all macro definitions	■	■	■	3.84
RP	Repeat command	■	■	■	3.85
RQ	Generate interrupt	■	■	■	3.86
RS	Reboot system	■	■	■	3.87
SB	Set bits high	■	■	■	3.88
SD	Speed divide	■	■	■	3.89
SE	Simultaneous command execution	■	■	■	3.90
SL	Set soft (travel) limits	■	■	■	3.91
SR	Select baud rate	■	■	■	3.92
ST	Stop motion	■	■	■	3.93
SV	Set variable value	■	■	■	3.94
SY	Set axes for simultaneous execution	■	■	■	3.95
TB	Tell error buffer contents	■	■	■	3.96
TE	Tell error code	■	■	□	3.97
TF	Tell filters (PID)	■	■	■	3.98
TG	Toggle bits	■	■	■	3.99
TL	Tell soft limits and follow error	■	■	■	3.100
TM	Tell memory	■	■	■	3.101
TP	Tell actual position	■	■	■	3.102

Cmd.	Description	IMM	PGM	MIP	Page
TPE	Tell positon in encoder units	■	■	■	3.103
TPI	Tell position in motor step units	■	■	■	3.104
TR	Initialize motion tracing mode	■	■	■	3.105
TS	Tell status	■	■	■	3.106
TT	Tell motion trace data	■	■	□	3.107
TV	Tell velocity	■	■	■	3.108
TY	Select stage type	■	■	■	3.109
UA	Set unit acceleration	■	■	□	3.110
UF	Update PID filters	■	■	■	3.112
UP	Move to absolute unit position	■	■	■	3.113
UR	Units position relative	■	■	■	3.115
US	Define resolution	■	■	□	3.117
UU	Select positioning unit	■	■	□	3.118
UV	Set unit velocity	■	■	■	3.119
UW	Wait for position crossing in units	■	■	□	3.120
VA	Set velocity value	■	■	■	3.121
VB	Set base velocity: start/stop velocity	■	■	■	3.122
VE	Tell firmware version	■	■	■	3.123
VR	Velocity relative	■	■	■	3.124
VS	Sample-time velocity mode	■	■	■	3.125
WA	Wait for all axes	■	■	■	3.126
WB	Wait for bit level, then execute	■	■	■	3.127
WD	Write value to D/A channel	■	■	■	3.128
WHILE/WEND	WHILE bit(s) high/low … WEND	■	■	■	3.129
WP	Wait for position, then execute	■	■	■	3.130
WS	Wait for stop plus, then execute	■	■	■	3.131
WT	Wait time, then execute next command	■	■	■	3.132
XX	Purge memory	■	□	□	3.133
%	Quit program entry mode	■	□	□	3.134
‘	Program line comments	□	■	□	3.135
#	Emergency stop	■	□	■	3.136

3.6 Description of Commands

The MM3000 command set consists of over 100 commands.

The extensive command set exists to facilitate application development for wide range of applications and needs. However, most simple positioning can be done with just a few commands:

- ***VA*** — set velocity
- ***AC*** — set acceleration
- ***PR*** — position relative
- ***PA*** — position absolute
- ***TS*** — tell status
- ***TP*** — tell position
- ***WS*** — wait for stop
- ***TY*** — select stage type

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxAB**

PARAMETERS
Description **xx** [int] — axis number

DESCRIPTION This command stops motion immediately and abruptly with fast deceleration.

If the MM3000 is executing a wait command, e.g., WA, WS, WP or WT, when this command is issued, AB will be queued and only executed after execution of all previous commands is finished.

Use the # command to stop motion immediately at any time.

RETURNS none

ERRORS E01 — BAD COMMAND

REL. COMMANDS
— emergency stop
ST — stop motion
MF — motor OFF
MO — motor ON

EXAMPLE
```
2AB                 / abort axis 2 motion
```

AC — set acceleration

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxACnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — acceleration value

Range

xx — **1** to **4**
nn — **250** to **1,000,000,000** **(DC Motor)**
15,000 to **450,000,000** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets acceleration and deceleration of the trapezoidal velocity profile for an axis. The value remains in effect until changed to another value. Note that the acceleration may not be changed during motion. For stepping motors, the AC parameter may be further modified with the SD command. See the SD command description details.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E29 — SYSTEM IS BUSY

REL. COMMANDS

VA — set velocity absolute
PA — execute an absolute motion
PR — execute a relative motion

EXAMPLE **4AC50000** / *set axis 4 acceleration/deceleration to 50000*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **ADnn**

PARAMETERS

Description	**nn** [int]		
Range	**nn**	—	**0** to **30** **15,000** to **450,000,000**
Units	**nn**	—	none
Defaults	**nn**	missing:	defaults to 0
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets the MM3000 device address for IEEE488 and RS-232C daisy-chain communications (see Appendix E for more information on daisy-chaining).

Parameter **nn** overrides internal dip switch address settings, takes effect immediately and is stored in non-volatile memory.

In case **nn** = 0, the MM3000 will set the RS-232C daisy-chain address to 0, but will set the IEEE488 device address to 1 in order to avoid an IEEE488 bus controller address conflict.

To query the current AD setting, simply append a question mark (?) to the command, i.e., AD ?.

RETURNS none or current address

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **DC** — Enable/disable RS-232C daisy-chain

EXAMPLE

```
AD 1          / set device address to 1
AD ?          / query current AD setting
   1          / MM3000 response
```

BA — enable backlash compensation

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxBAnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	backlash compensation value
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **65535**
Units	**xx**	—	none
	nn	—	encoder counts or steps
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		disable backlash compensation
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command invokes the automatic backlash compensation function. In this mode the MM3000 will modify the positioning command by adding **nn** counts or steps whenever there is a motion reversal. **nn** should be equal to the backlash of the system. This function is useful in those systems without direct position feedback.

The parameter **nn** is calculated according to the formula:

$$nn = \text{integer}\left(\frac{\text{backlash}}{\text{resolution}}\right)$$

where backlash is the measured backlash of the positioner.

Before issuing the BA command, a positive direction move with a distance greater than the backlash must be executed. In addition, DC motors must have their PID parameters adjusted to eliminate any overshoot.

Note:
This mode is disabled by issuing the BA command without any parameters. Once a parameter **nn** is loaded it remains in non-volatile memory for use after power up.

Note:
After each power up cycle, perform a home search to ensure proper operation of the backlash compensation. See also OV command.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
CO — enable linear compensation
OV — set overshoot value for home search

EXAMPLE

```
2PR1000          / move positive to eliminate backlash
2BA10            / set backlash compensation to 10 counts (or steps)
   •
   •
   •
2BA              / disable backlash compensation
2BA?             / report nn setting
   10            / response from MM3000
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **BInn$_1$, nn$_2$, nn$_3$, …, nn$_8$**

PARAMETERS

Description	**nn** [int]	—	I/O bit number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**nn**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION Before a bit can be used as an input, it must be defined as an input bit. This command is used to define the specified I/O bits as an input. Note that the unspecified bits remain unaffected. All I/O bits are automatically configured as inputs after a system reset.

The I/O bits can be accessed at the General Purpose I/O connector on the rear panel of the MM3000. See Appendix B for pinouts and electrical requirements.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
BO — define I/O bits as outputs
RB — read input bit values

EXAMPLE
```
BI1,2,5          / define I/O bits 1,2, and 5 as inputs
```

BO — define I/O bits as outputs

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **BO**nn_1, nn_2, nn_3, ..., nn_8

PARAMETERS

Description	**nn** [int]	—	I/O bit number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**nn**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION Before a bit can be used as an output, it must be defined as an output bit. This command is used to define the specified I/O bits as outputs. Note that the unspecified bits remain unaffected. All I/O bits are automatically configured as inputs after a reset.

The I/O bits can be accessed at the General Purpose I/O connector on the rear panel of the MM3000. See Appendix B for pinouts and electrical requirements.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
SB — set I/O output port bits
TG — toggle I/O output port bits
BI — define I/O bits as inputs

EXAMPLE
```
BO1,2,5          / set I/O bits 1,2, and 5 as outputs
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **CBnn$_1$, nn$_2$, nn$_3$, ..., nn$_8$**

PARAMETERS

Description	**nn** [int]	—	I/O bit number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**nn** missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION Assuming I/O bit(s) were previously defined as outputs with theBO command, this command sets the bit(s) low. This command is useful to synchronize external devices to internal events (for example, indicating when motion is complete).

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
BO — define I/O bits as outputs
SB — set I/O output bits
TG — toggle I/O output bits

EXAMPLE

```
BO1,3,8          / define bits 1, 3, 8 as outputs
CB1,3,8          / set output bits 1, 3, 8 low, i.e., output zero volts on bit1, 3, 8
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxCLnn$_1$, nn$_2$, nn$_3$**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn$_1$ [int]	—	max. following error
	nn$_2$ [int]	—	deadband
	nn$_3$ [int]	—	sample interval
Range	**xx**	—	**1** to **4**
	nn$_1$	—	**1** to **65535**
	nn$_2$	—	**0** to **65535**
	nn$_3$	—	**0** to **255**
Units	**xx**	—	none
	nn$_{1-3}$	—	none
Default	**xx**	missing:	last axis specified with previous command
		out of range:	BAD COMMAND
	nn$_{1-3}$	missing:	E02 ILLEGAL PARAMETER
		out of range:	E02 ILLEGAL PARAMETER

DESCRIPTION

This command is used to set parameters associated with closed loop stepper motor operation. It is also used to enable (e.g., 2CL ON) or disable (e.g., 2CL OFF) closed loop operation.

Appending a ? to the CL command (e.g., 2 CL ?) will return the current parameter settings and ON/OFF status.

Note that encoder feedback must be enabled (i.e., FM bit-0 must equal 0) for closed loop operation.

Following error threshold (**nn$_1$**) is the maximum deviation from target position permitted before the MM3000 will automatically abort motion on the offending axis, revert to default open-loop mode, record an error (see TB command), and alert the host computer via interrupt (seeFI command).

Deadband (**nn$_2$**) is the maximum allowable error which will NOT trigger a position error correction. This parameter is necessary because of real world electro-mechanical imprecision, (e.g., stage backlash, microstepping inaccuracy, etc...) which may result in motor oscillation.

Sample interval (**nn$_3$**) is the time between position error corrections. Sample intervals are in multiples of 0.1 sec (e.g., n_3=0 (0.1s), n_3=1 (0.2s), etc..) and can be as long as 25.6 seconds.

Note that closed loop stepper mode is automatically disabled if the CL OFF command is executed, joystick (JY) mode is activated, an emergency stop or STOP ALL is invoked, or a system reset occurs.

RETURNS none or current setting (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH
E33 — ENCODER FEEDBACK NOT ENABLED
E[8-11] AXIS [1-4] — MOTOR FOLLOWING ERROR

REL. COMMANDS **FM** — format motion
ER — encoder ratio

EXAMPLE

```
1FM &FE          / enable encoder feedback
1CL 50,1,0       / set closed loop stepper parameters
1CL ON           / enable closed loop stepping
```

CM — create macro

USAGE ■ IMM ☐ PGM ■ MIP

SYNTAX **CMnn; command 1; command 2; ...**

PARAMETERS

Description	**nn** [int]	—	macro number
Range	**nn**	—	**1** to **127**
Units	**nn**	—	none
Defaults	**nn**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command permits the user to create a macro. Macro definitions combine multiple MM3000 instructions into a single command. 5K-bytes of non-volatile memory are allocated for macro definitions. Macros can be executed either from a program or in command mode (seeEM command). Also, previously stored macros can be executed with the optional handheld keypad (see Section 6.2). Note that any duplication of definitions will result in an E12 MACRO ALREADY EXISTS error. Up to 20 macros can be nested within each other.

Note:
All commands within a macro have to be one string (see example). A maximum of 80 characters can be stored in a single macro. The end of a macro is indicated to the MM3000 upon receiving a carriage return.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E12 — MACRO ALREADY EXISTS

REL. COMMANDS
RM — reset macro(s)
EM — execute macro
LM — list macro(s)

EXAMPLE
```
CM1;2PR-100;3PR100  / create macro to move axis 2 and 3
EM1                 / execute macro 1
```

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxCOnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	linear compensation value
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **65535**
Units	**xx**	—	none
	nn	—	encoder counts or steps
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		disable linear compensation
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command permits the user to compensate for linear positioning errors due to inaccuracies of the stage. That type of error decreases or increases actual motion linearly over the travel range.

The parameter **nn** is calculated according to the formula:

$$\text{nn} = \text{integer}\left(\frac{-\text{travel}}{\text{error}}\right)$$

where travel is the measured travel range over which a certain error was accumulated, e.g., let's assume a stage has a linear travel of 100 mm and accumulates a linear error of 0.003 mm over the complete travel range. nn would be:

$$\text{nn} = \left(\frac{-100\ \text{mm}}{0.003\ \text{mm}}\right)\ \text{integer} = -3333$$

This function is useful for systems without direct position feedback. Before issuing a CO command, a positive move has to be performed.

Note:
After each power up cycle, perform a home search to ensure proper operation of the linear compensation.

Note:
This mode can be disabled by sending a CO command without **nn** parameter. Once a parameter **nn** is entered, it remains valid even after a power cycle (off/on).

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **BA —** backlash compensation

EXAMPLE

```
CO 1000          / compensate for linear error by adding 1000 counts/steps
                 / linearly over the travel range of the stage
   •
   •
   •
CO?              / query setting
1000             / controller response
```

CP — compile program

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **CP**

PARAMETERS none

DESCRIPTION This command compiles all instructions downloaded into the MM3000 program memory. Commands, jumps, labels and parameters are evaluated at this time. If one or more errors are detected, the MM3000 sends all error messages. If no errors are encountered, then the MM3000 is ready to send the COMPILATION COMPLETE message. Therefore, immediately after you issue a CP command, execute the MM3000 read function, and repeat the read function until the response is END. See also Section 3.

RETURNS COMPILATION COMPLETED / no errors in program
END
— or —
A list of errors terminated with END / errors in program

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E19 — NOT ALLOWED IN PROGRAM EXECUTION MODE
E20 — TARGET LABEL NOT IN PROGRAM
E21 — REDEFINED LABEL
E30 — NESTED WHILE/WEND NOT PERMITTED
E31 — WEND WITHOUT WHILE FOUND
E32 — WHILE WITHOUT WEND FOUND

REL. COMMANDS
EP — enter programming mode
% — quit programming mode
EX — execute stored program

EXAMPLE

```
EP                  / enter program; commands are not executed after the
                    / MM3000 receives this command
2PR 1000            / move to position 1000 relative (axis 2)
2WS                 / wait for axis to stop
%                   / exit program mode
CP                  / compile program
    COMPILATION COMPLETED       / response from MM3000
END
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxDA**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command reports the desired acceleration and deceleration previously entered with the AC command. Note that, regardless of the FM command configuration, DC motor axes will always respond in terms of counts/sec^2 while stepping motor modules respond in steps/sec^2. The response for stepping motor modules includes the divide factor set by the SD command.

RETURNS Acceleration values for specified axis

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **AC —** set acceleration

EXAMPLE

```
2AC 300000          / set acceleration of axis 2 to 300000
2DA                 / read acceleration of axis 2
    300000 COUNTS/SEC^2     // dc motor response
3DA                 / read acceleration of axis 3
    100000 STEPS/SEC^2      // stepping motor response
```

DC — enable/disable RS-232C daisy-chain mode

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **DCnn**

PARAMETERS

DESCRIPTION	**nn** [int]	—	command
Range	**nn**	—	**0** or **1**
Units	**nn**	—	none
Default	**nn**	missing:	zero assumed
		out of range:	E02 ILLEGAL PARAMETER

DESCRIPTION This command enables or disables RS-232C serial interface daisy-chaining (see Appendix E for more information on daisy-chaining).

If **nn** equals 0, daisy-chaining is disabled. If parameter **nn** equals 1, daisy-chaining is enabled.

The DC command takes effect immediately (it is not stored in a command queue) and parameter **nn** is stored in non-volatile memory.

To query the current DC setting, append a question mark (?) to the command, i.e., DC ?.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **AD** — Set Address

EXAMPLE

```
DC 1          / enable RS-232C daisy-chaining
DC 0          / disable RS-232C daisy-chaining
DC ?          / query current DC setting
   0          / MM3000 response
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxDH**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command defines the current position as HOME position. This means the current position becomes the zero reference for subsequent absolute positioning commands. DH also defines the floating home point, i.e., the command OR0 (go to floating home) will return the stage to this location.

RETURNS none

ERRORS E01 — BAD COMMAND

REL. COMMANDS **OR0—** execute a home search cycle (go to position 0)

EXAMPLE

```
2 PR 1000          / move to position 1000 relative to current position
DH                 / define new position as HOME position
  •
  •
  •
2 OR0              / move to HOME position
```

DL — define label

USAGE ☐ IMM ■ PGM ☐ MIP

SYNTAX **DLaa**

PARAMETERS

Description	**aa** [char]	—	label name
Range	**aa**	—	**A** to **Z**
Units	**aa**	—	none
Defaults	**aa** missing:		E01 - BAD COMMAND
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION The DL command defines a label to be used as a target for JL and IF/THEN commands in a downloaded program.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
JL — jump to label
IF — IF/THEN

EXAMPLE

```
EP              / enter program mode
DL A            / define label A
  •
  •
  •
JL A 4          / jump to label A; perform 4 loops
%               / exit program mode
CP              / compile program
EX              / execute program
```

read desired position — DP

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxDP**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command reports the last desired position, the destination of a stage. For stepping motor modules, the response will be either in encoder counts or steps depending on the corresponding FM command configuration (see FM command). DC motor modules respond always in encoder counts.

RETURNS Desired position for axis specified

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
PA — move to an absolute position
PR — move to a relative position
TP — tell current position

EXAMPLE

```
3PA1000          / move axis # 3 to absolute position 1000
DP               / read position on axis # 3
  +1000 COUNTS   / controller returns position 1000 counts for axis # 3
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxDSnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	sampling coefficient
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **255**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E01 - BAD COMMAND
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION The sampling interval used for the KD gain value is set with this instruction according to the following formula: T = (nn + 1) x 256 micro-seconds, where T is the sample interval. Note that this is merely the **sampling** interval. The derivative of the sampled position multiplied with KD contributes each sampling time, i.e., 256 micro-seconds, to the control input.

An UF instruction has to be issued to update the value.

The currently set value can be retrieved with the TF command.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
KD — set PID derivative value
UF — update filter
TF — tell filter

EXAMPLE
```
3DS0          / set axis # 3 derivative sampling interval to 256us
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxDV**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command reports the desired velocity requested with the VA or VR commands. Note that, regardless of the FM command setting, DC motor modules will always respond in terms of counts/sec while stepping motor modules respond in steps/sec. The response for stepping motor modules also includes the base velocity set with the VB command and the speed divide factor set by the SD command.

RETURNS Present set velocity for the specified axis

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
VA — set absolute velocity
VR — set relative velocity
DP — read desired position

EXAMPLE
```
2DV                  / read desired velocity on axis # 2
    5000 COUNTS/SEC  / dc motor response
3DV                  / read desired velocity on axis # 3
    100–20000 STEPS/SEC  / stepping motor response
                         / 100 is base velocity (see VB command)
```

EM — execute macro

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **EMnn**

PARAMETERS

Description	**nn** [int]	—	macro number
Range	**nn**	—	**1** to **127**
Units	**nn**	—	none
Defaults	**nn**	missing:	E01 - BAD COMMAND
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command executes macros previously created with theCM command. Macros may be called and executed at any time. They can be executed from within a program, in command mode or with the optional keypad. Note that commands stored in macro definitions are not evaluated until the macro is executed. Therefore, syntax errors, parameters errors, etc., entered along with the CM command will appear at the time of the execution of the macro.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E15 — MACRO NOT FOUND

REL. COMMANDS
CM — create macro(s)
LM — list macro(s)
RM — reset macro(s)

EXAMPLE
```
CM2;2PA1000;WS;PA0;WS      / create macro #2
EM2                        / execute the macro
```

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **EP**

PARAMETERS none

DESCRIPTION This command places the MM3000 into the programming mode. All commands received after an EP command are saved in non-volatile memory. While in this mode, the command input channel is redirected from the normal verification and execution to simply saving commands without evaluation.

/QP starts a new program. Up to 99 programs can be stored.

The % command exits program entry mode and returns the MM3000 to command mode.

Any previous programs in memory will be erased when EP is issued.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E16 — MISSING PROGRAM
E17 — PROGRAM NOT COMPILED

REL. COMMANDS
/QP — start new program
% — quit programming mode
LP — list program
EX — execute program
CP — complile program

EXAMPLE

```
EP                    / enter program entry mode
  •
  •
  •
/QP                   / start program 2
  •
  •
  •
%                     / exit program entry mode
CP                    / compile programs
    COMPILATION COMPLETE      / response from MM3000
END                           / if no errors in program
```

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxERnn:mm**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	encoder counts
	mm [int]	—	step pulses
Range	**xx**	—	**1** to **4**
	nn	—	**1** to **10000**
	mm	—	**1** to **10000**
Units	**xx**	—	none
	nn	—	encoder counts
	mm	—	step pulses
Defaults	**xx** missing:		axis selected with last command
	out of range:		E01 - BAD COMMAND
	nn missing:		E01 - BAD COMMAND
	out of range:		E02 - ILLEGAL PARAMETER
	mm missing:		E01 - BAD COMMAND
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets a ratio between step pulses that are sent by the controller to the driver and the number of encoder counts that are expected back by the stage.

PA and PR commands use either encoder counts or step pulses. The choice is made with the FM command. If a stage has an encoder, the user may select the encoder count for the PA and PR commands. In this case, the encoder ratio must be set, otherwise there may be errors in positioning.

The TY command sets the proper ratio for all Newport stages and it is not necessary to explicitly send the ER command.

Typical encoder ratios for Newport stages are: ER 1:1
ER 1:10

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS **FM —** format motion

EXAMPLE
2ER1:10 / *1 encoder count per 10 step pulses on axis 2*
1ER10:128 / *10 encoder counts per 128 steps on axis 1*

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **EXnn**

PARAMETERS

Description	**nn** [int]	—	program number
Range	**nn**	—	**1** to **99**
Units	**nn**	—	none
Defaults	**nn**	missing:	executes last specified program
		out of range:	E01 - BAD COMMAND

DESCRIPTION Successfully entered (see EP command) and compiled programs (see CP command) stored in theMM3000 memory are executed with this command. While in program execution mode, it is still possible to transmit real-time commands to the MM3000 for execution. Any command errors or motion errors (i.e. activated travel limit) detected during this mode will abort the program and cause the MM3000 to re-enter command mode.

The EX command automatically compiles any uncompiled programs and executes them if no errors exist. Yet, it is recommended tocompile programs first with the CP command to ensure error free programs before attempting to execute them.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
EP — enter program mode
QP — quit program
CP — compile a program

EXAMPLE
```
3EX              / execute program # 3
```

FE — set maximum following error DC Motor

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxFEnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — maximum allowed following error

Range

xx — **1** to **4**
nn — **1** to **32767**

Units

xx — none
nn — encoder counts

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the maximum allowed following error for an axis. This error is defined as the difference between the real position and the theoretical position of a motion device. The real position is the one reported by the position sensing device (encoder, scale, etc.) and the theoretical position is calculated by the controller each servo cycle. If, for any axis and any servo cycle, the following error exceeds the preset maximum allowed following error, the controller stops motion and turns power off to the respective motor. See Section 4.2.1 for additional information.

See also FO command.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS **TF** — tell filter

EXAMPLE **2FE50** / *set axis #2 maximum following error to 50 encoder counts*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **FOnn**

PARAMETERS

Description	**nn** [hex]	—	event selection
Range	**nn**	—	**00** to **FF**
Units	**nn**	—	none
Defaults	**nn**	missing:	defaults to 00
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command allows the user to enable or disable interrupts on selected events.

If the IEEE488 interface is the active port, an SRQ interrupt is generated when the selected event occurs. The host computer (i.e., GPIB controller) can then perform a Serial Poll to retrieve the interrupt status byte. (Note that the SPOLL response byte format is the same as in the TS command) The SRQ signal is automatically released after a Serial Poll.

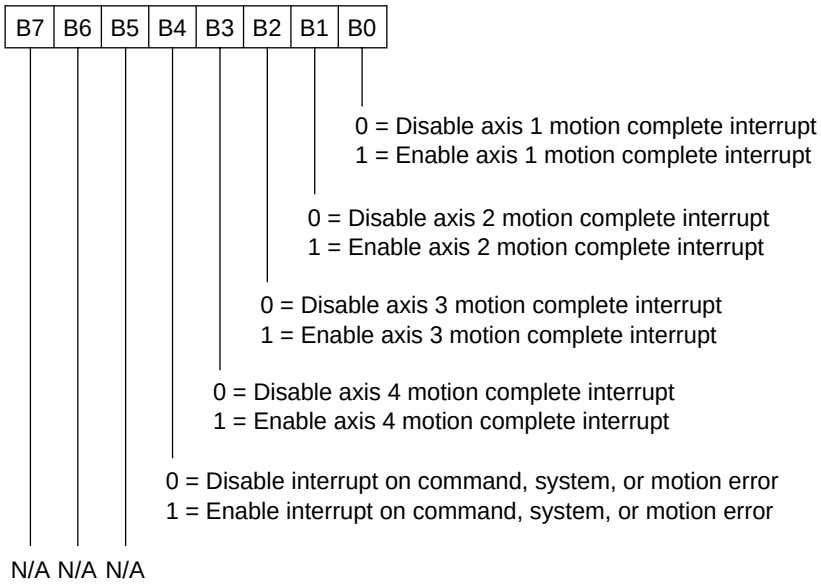
If the RS-232C serial interface is active, an exclamation character(!) (ASCII 33) is transmitted to the host. The TS command can be used to retrieve interrupt status if desired.

The FI parameter **nn** takes effect immediately after being received. The default is 00 after system reset.

To query the current FI setting simply append a question mark (?) to the command, i.e., FI?.

An OR (e.g., FI¦01) or AND (e.g., FI &FE) operation with the stored parameter **nn** can be performed to selectively clear or set specific bits.

The parameter **nn** is the hexadecimal representation of the bit pattern shown below. See Appendix for binary-to-hexadecimal conversion table.



RETURNS none or current setting (see example)

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

FS — format system
FO — format output
FM — format motion

EXAMPLE

```
FI 14          / generate interrupt on axis-3 motion complete or any error
FI ?           / query current FI setting
    14         / MM3000 response
FI &EF         / disable interrupt on any error
FI ¦03         / enable interrupt on axis 1 and axis 2 motion complete
FI ?           / query  current FI setting
    07         / MM3000 response (interrupt on axis 1, 2 or 3 motion
               / complete)
```

USAGE ■ IMM ■ PGM ■ MIP

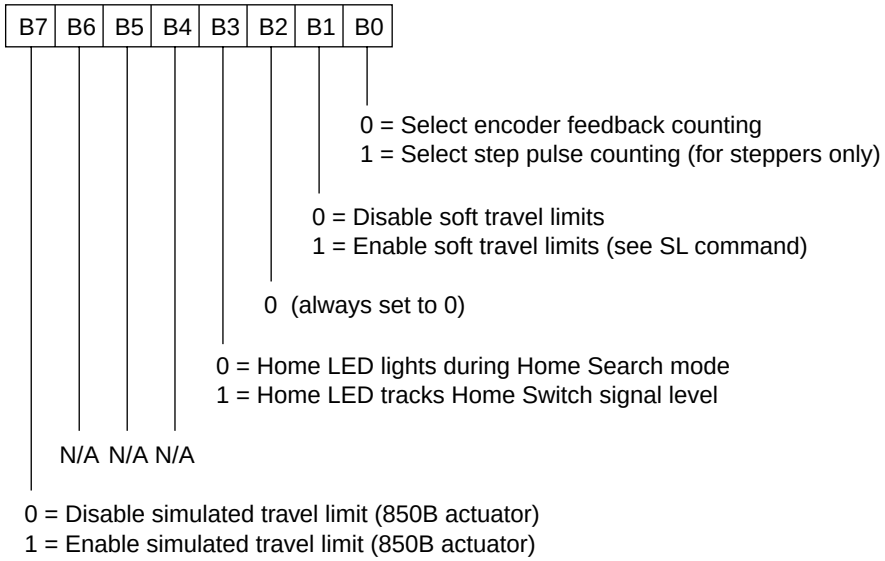
SYNTAX **xxFMnn**

PARAMETERS

Description	**xx** [int]		
	nn [hex]		
Range	**xx**	—	**1** to **4**
	nn	—	**00** to **FF**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 00
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command allows the user to format or configure axis specific features.

The parameter **nn** is the hexadecimal representation of the bit pattern shown below. See Appendix for binary-to-hexadecimal conversion.



BIT-0
If bit-0 equals 0, motion commands (e.g., PA, UP) and query commands (e.g., TP, UP?) will be based on encoder feedback not pulse output. This is the suggested mode for stages with encoders and is essential for closed loop stepper operation. However, if bit-0 equals 1 (and the axis is a stepper motor), encoder feedback is ignored and only step pulses are being counted. Note that this mode is ignored on DC servo driven axes and is typically used for stepper motor driven stages without encoders.

BIT-1
If bit-1 equals 0, soft travel limits are disabled. If bit-1 equals 1, soft travel limits are enabled (see SL command for more information on soft travel limits).

BIT-3
If bit-3 equals 0, the LED above the HOME pushbutton lights up only while the respective axis is performing a HOME search. If bit-3 equals 1, the LED lights up if the HOME Switch signal is a logical High and turns OFF if the signal is a logical Low, i.e., it changes state when the stage crosses the HOME switch.

BIT-7
If bit-7 equals 0, the axis will not operate in 850B simulated travel limit mode.
If bit-7 equals 1, the axis will operate in 850B simulated travel limit mode.

The FM parameter **nn** takes effect immediately after being received and is stored in non-volatile memory for automatic reloading after system reset. To query the current FM setting simply append a question mark (?) to the command (i.e., FM ?).

An OR (e.g., FM¦01) or AND (e.g., FM &FE) operation with the stored parameter **nn** can be performed to selectively clear or set specific bits.

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
FS — format system
FI — format interrupt
FO — format output

EXAMPLE

```
FM 82          / enable simulated travel limit and soft travel limit
FM ?           / query current FM setting
   82          / MM3000 response
FM &7F         / disable simulated travel limit
FM¦08          / make Home LED track Home Switch signal level
FM ?           / query  current FM setting
   0A          / MM3000 response
```

USAGE ■ IMM ■ PGM ■ MIP

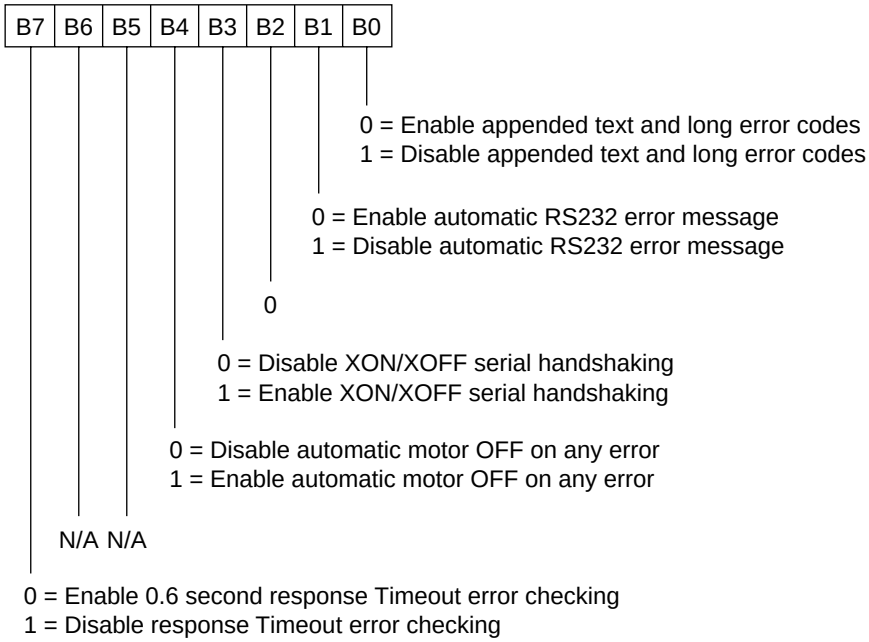
SYNTAX **FOnn**

PARAMETERS

Description	**nn** [hex]		
Range	**nn**	—	**0** to **FF**
Units	**nn**	—	none
Defaults	**nn**	missing:	defaults to 00
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to enable and disable various global system features.

The parameter **nn** is the hexadecimal representation of the bit pattern shown below. See Appendix for binary-to-hexadecimal conversion.



BIT-0
If bit-0 equals 0, the controller appends text to various query commands (e.g., TP, TB) for enhanced user friendliness. If bit-0 equals 1, the query response is abbreviated to facilitate faster communications.

BIT-1
If bit-1 equals 0, the controller automatically transmits error messages to the RS-232C serial link as they occur — unless the IEEE488 parallel link is the active port. This feature is suggested for use with RS-232C terminal emulation programs (e.g., EZ232). If bit-1 equals 1, the controller does not automatically transmit error messages, but the error status can be queried with the TB command. Note that bit-1 is automatically set to 1 while in daisy-chain mode (see DC command).

BIT-3
If bit-3 equals 0, RS-232C software handshaking is disabled. If bit-3 equals 1, RS-232C software XON/OFF handshaking is enabled. In this mode, if the 512-byte command becomes full, the MM3000 will transmit an XOFF (ASCII 19) character. As the MM3000 processes commands stored in its queue, an XON (ASCII 17) character will be transmitted to enable host-to-MM3000 communications. Conversely, the host computer can stop the MM3000

from transmitting characters to it by sending the XOFF (ASCII 19), but it must then transmit an XON (ASCII 17) within 0.6 seconds to keep the MM3000 from generating an E03 COMMUNICATION TIMEOUT error.

BIT-4
If bit-4 equals 1, motor power is automatically removed on all axes on the occurrence of any command error, positioning or system error. Motor power can be individually enabled with the MO or any move (e.g., PA, MV) command. If bit-4 equals 0, all motors are not automatically turned OFF on an error.

BIT-7
If bit-7 equals 0, the controller will wait up to 600 milliseconds for the host computer to accept a query command (e.g., **TP**) response. After this period, an E03 COMMUNICATION TIMEOUT error message will be generated. If bit-7 equals 1, the controller will wait indefinitely for the host computer to accept a query command response. In case the controller does not accept the data, only the front panel STOP ALL or power ON/OFF push buttons will restore the system.

The FO parameter **nn** takes effect immediately after being received and is stored in non-volatile memory for automatic reloading after system reset.

To query the current FO setting simply append a question mark (?) to the command (i.e., FO?).

An OR (e.g., FO¦01) or AND (e.g., FO &FE) operation with the stored parameter **nn** can be performed to selectively clear or set specific bits.

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
FS — format system
FI — format interrupt
FM — format motion

EXAMPLE

```
FO 1          / disable appended text and long error codes
FO?           / query current FO setting
   01         / MM3000 response
FO &FE        / enable appended text and long error codes
FO¦82         / disable Timeout and automatic RS-232C error message
```

USAGE ■ IMM ■ PGM ■ MIP

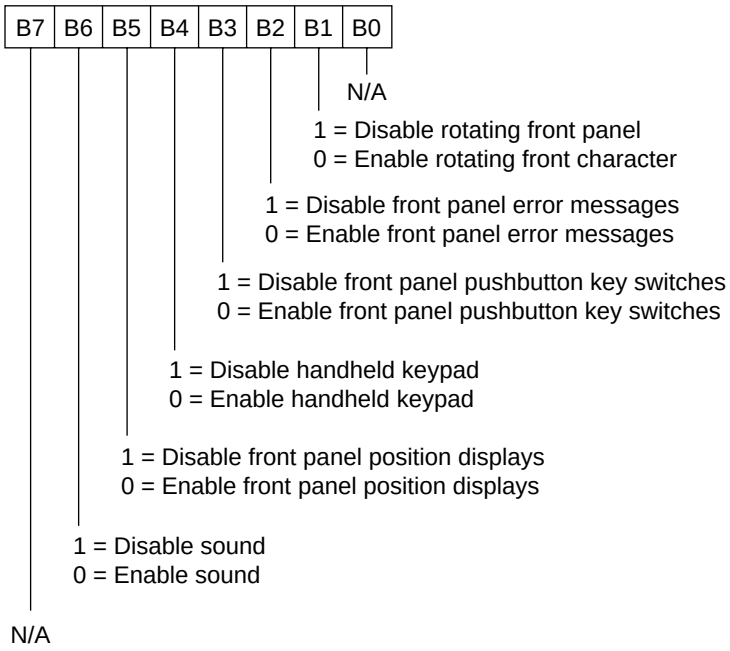
SYNTAX **FSnn**

PARAMETERS

Description	**nn** [hex]		
Range	**nn**	—	**0** to **FF**
Units	**nn**	—	none
Defaults	**nn**	missing:	defaults to 00
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to enable and disable various control and front panel display features.

The parameter **nn** is the hexadecimal representation of the bit pattern shown below. See Appendix for binary-to-hexadecimal conversion.



BIT-1
If bit-1 equals 0, then a rotating character is displayed on an empty front panel axis. If bit-1 equal 1, rotating character is not displayed. This feature confirms that the CPU is actively updating all front panel displays.

BIT-2
If bit-2 equals 0, command, system, or motion error messages are temporarily (4 seconds) displayed on the front panel. If bit-2 equals 1, error messages are not displayed on the front panel. This mode can be used if displayed messages cause host timeout.

BIT-3
If bit-3 equals 0, all front panel pushbutton switches are enabled. If bit-3 equals 1, all front panel pushbutton switches (except STOP ALL and POWER) are disabled. Note that after a system reset bit-3 is automatically cleared to 0.

BIT-4
If bit-4 equals 0, the handheld keypad is enabled. If bit-4 equals 1, the handheld keypad is disabled. Note that after a system reset bit-4 is automatically cleared to 0.

BIT-5
If bit-5 equals 0, front panel position displays are enabled. If bit-5 equals 1, all position displays are disabled. This mode is recommended during precision multi-axis synchronization sequences. Note that after a system reset bit-5 is automatically cleared to 0.

BIT-6
If bit-6 equals 0, the controller will chirp after a valid front panel keypress and generate a long BEEP after any error. If bit-6 equals 1 then all sound is disabled.

The FS parameter **nn** takes effect immediately after being received and is stored in non-volatile memory. However, bits 3, 4 and 5 are reset to 0 after system reset.

To query the current FS setting simply append a question mark (?) to the command (i.e., FS ?).

An OR (e.g., FS¦01) or AND (e.g., FS &FE) operation with the stored parameter **nn** can be performed to selectively clear or set specific bits.

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
FI — format interrupt
FO — format output
FM — format motion

EXAMPLE

```
FS 44          / disable sound and front panel error messages
FS ?           / query current FS setting
   44          / MM3000 response
FS &FB         / enable front panel error messages
FS ¦20         / disable front panel position displays
FS ?           / query  current FS setting
   60          / MM3000 response (position displays and sound disabled)
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **IEnn**

PARAMETERS

Description	**nn** [int]	—	time interval value
Range	**nn**	—	**0** to **10000**
Units	**nn**	—	milliseconds
Defaults	**nn**	missing:	disable internal execution mode
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets the time interval execution mode, i.e., a delay equal to the command parameter **nn** in milliseconds will be inserted between every line of MM3000 commands.

This command is useful for contouring with DC and stepping motors. For DC motor control, the MM3000 can be commanded to change position on the fly. To traverse a contour, define the contour as position versus discrete time. Program the time interval with this command and then send the calculated positions.

For stepping motor control, the MM3000 can be commanded to change the velocity on the fly. To traverse a contour, define the contour as velocity versus discrete time. Program the time interval with this command, initiate the motion, and then send the calculated velocities.

Issuing IE without a parameter or with a 0 will disable the mode.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE

```
IE10          / set command execution interval to 10 milliseconds
VA1000        / each speed command in the series will be executed
VA1050        / at intervals of 10 milliseconds
VA1100
```

IF .. THEN — program execution flow control

USAGE ☐ IMM ■ PGM ■ MIP

SYNTAX **IF n_1x_1, n_2x_2, …, n_8x_8, THEN label**

PARAMETERS

Description	**n** [int]	—	GPIO input bit n
	x [char]	—	logic level of bit n
	label	—	jump label defined with DL command
Range	**n**	—	**1** to **8**
	x	—	**L** or **H**
	label	—	**A** to **Z**
Units	none		
Defaults	**nx** missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER
	label missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command uses a label previously defined with the DL command as a jump target if the specified bit condition is true. Each time the IF instruction is encountered, the bit condition is tested. If the bit condition is false, program execution continues with the instruction immediately following the THEN command.

Note that the bits used in this command have to be defined as input bits with the BI command first.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
BI — define input bits
WHILE/WEND
WB — wait bit high/low

EXAMPLE

```
EP                  / enter program mode
BI2,7,8             / define bits 2, 7, 8 as inputs
DL A                / define label A
3PR1000;WS          / initiate move and wait for stop
IF 2H,7L, 8H THEN A / jump to label A if bit 2 is high, bit 7 is low and bit
                    / 8 is high
%                   / exit program mode
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxILnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	integrator limit
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **32767**
Units	**xx**	—	none
	nn	—	encoder counts
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E02 - ILLEGAL PARAMETER
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to set the value for the filter integration limit coefficient IL. The integral term of the filter equation is not allowed to exceed this value. The limiting process is useful for preventing integral wind-up. Like all PID filter parameters, the value is not changed until theUF (update filter) command is issued.

See Section 4.3 before using this command.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
KI — set integral gain factor
UF — update filter
TF — tell filter

EXAMPLE

```
3IL10          / set integrator limit  for axis # 3 to 10
  •
  •
  •
3UF            / update PID filter; only now the IL command takes effect
```

JA — set jog acceleration

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxJAnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — acceleration value

Range

xx — **1** to **4**
nn — **250** to **1,000,000,000** **(DC Motor)**
nn — **15,000** to **450,000,000** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the acceleration and deceleration portion for positioning with either jog button on the front panel.

For stepping motors, the JA parameter may be further modified with the SD command. See the SD command for further details.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SD — speed divide
JW — set jog low speed
JH — set jog high speed

EXAMPLE **3JA50000** / *set jog acceleration to 50000 for axis #3*

set jog high velocity — JH

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxJHnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — integrator limit

Range

xx — **1** to **4**
nn — **0** to **1 000 000** **(Stepping Motor)**
100 to **1 500 000** **(DC Motor)**

Units

xx — none
nn — steps/second or counts/second

Defaults

xx missing: last axis specified with previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets the desired value for the velocity at which a motor moves when the HIGH SPEED button in connection with either jog button on the front panel is pressed.

For stepping motors, the JH command may be further modified with the SD command. Also, the value set with the JH command must not be lower than the value set with the VB command.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SD — speed divide
JW — set jog low velocity
VB — set base velocity

EXAMPLE

```
3JH10000        / set jog high velocity for axis # 3 to 10000
```

JL — jump to label

USAGE ☐ IMM ■ PGM ■ MIP

SYNTAX **JLaann**

PARAMETERS

Description

aa [char] — label
nn [int] — repetition count

Range

aa — **A** to **Z**
nn — **0** to **65535**

Units

aa — none
nn — none

Defaults

aa missing: E01 - BAD COMMAND
out of range: E02 - ILLEGAL PARAMETER
nn missing: loop indefinitely
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command changes the flow of the program execution by jumping to a predefined label. Each time this instruction is encountered,**nn** is decremented by one. If the count is non-zero after the decrement, program execution will jump to the specified label. When the count reaches zero, program execution continues with the instruction immediately following the JL command.

If the **nn** is set to zero or not specified, the program will loop indefinitely!

RETURNS none

ERRORS E02 — ILLEGAL PARAMETER

REL. COMMANDS

DL — define label
EP

EXAMPLE

```
EP              / enter program mode
DL A            / define label number 3
  •
  •
  •
JL A3           / jump to label A 3 times
%
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxJWnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	integrator limit
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **1 000 000** for stepper motors **100** to **1 500 000** for dc motors
Units	**xx**	—	none
	nn	—	steps/second or counts/second
Defaults	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the desired value for the velocity at which the motor moves when either jog button on the front panel is pressed.

For stepping motors, the JW command may be further modified with the SD command. Also, the value set with the JW command must not be lower than the value set with the VB command.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
SD — speed divide
JH — set jog low velocity

EXAMPLE **3JW1000** / *set jog low velocity for axis # 3 to 1000*

JY — enable joystick control

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxJYnn**

PARAMETERS

Description	**xx** [int]	—	motor axis number
	nn [int]	—	joystick axis
Range	**xx**	—	**1** to **4**
	nn	—	**–4** to **4**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		disable joystick
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command enables the joystick. An optional joystick can be connected to the joystick connector on the MM3000 (see Section 6.1). It can control the speed and the direction of up to 4 motors. **nn** defines the joystick channel used for the axis defined by **xx**. The sign of **nn** determines the relation between the direction of motor movement and the direction of joystick movement.

Issuing this command with a parameter equal to zero disables joystick control.

See Section 6.1 in this manual for a more detailed explanation of the joystick.

Note:
It is necessary to turn on the motor (MO command) before using the joystick.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
AC — set acceleration
VA — set absolute velocity
MO — motor on

EXAMPLE

```
1JY2          / control axis 1 with joystick channel 2
1MO           / turn motor on
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxKDnn**

PARAMETERS

Description
xx [int] — axis number
nn [int] — derivative gain factor Kd

Range
xx — **1** to **4**
nn — **0** to **32767**

Units
xx — none
nn — none

Defaults
xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command is used to set the value for the filter derivative coefficient KD of the PID filter. Like all filter parameters, this value is not changed until the UF (Update Filter) command is issued.

See Section 4.3 for an explanation on the use of DC motor filter parameters.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
KI — set integral gain factor
KP — set proportional gain factor
DS — set derivative sampling interval
UF — update filter
TF — report PID filter settings
TY — motor type

EXAMPLE

```
3KD10          / set derivative gain factor for axis # 3 to 10
  •
  •
  •
3UF            / update filter, KD value takes effect now
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxKInn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	integral gain factor Ki
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **32767**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to set the value for the filter integral coefficient KI of the PID filter. Like all PID parameters, this value is not changed until theUF (Update Filter) command is issued.

See Section 4.3 for an explanation on the use of DC motor filter parameters.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
KD — set derivative gain factor
KP — set proportional gain factor
IL — integration limit
TF — tell filter
TS — type

EXAMPLE

```
3KI10          / set integral gain factor for axis # 3 to 10
  •
  •
  •
3UF            / update filter, KI value takes effect now
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxKPnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	proportional gain factor Kp
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **32767**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to zero
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to set the value for the proportional filter coefficient KP of the PID filter. Like all PID parameters, this value is not changed until the UF (Update Filter) command is issued.

See Section 4.3 for an explanation on the use of DC motor filter parameters.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
KD — set derivative gain factor
KI — set integral gain factor
UF — update filter
TF — tell filter
TS — type

EXAMPLE

```
3KP10          / set proportional gain factor for axis # 3 to 10
  •
  •
  •
3UF            / update PID filter; KP value takes effect now
```

LM — list all macro definitions

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **LM**

PARAMETERS none

DESCRIPTION This command directs the MM3000 to output a list all of the stored macros previously created with the CM (create macro) command. The macro definitions are listed in the order they were saved. This command is useful to determine whether or not a macro already exists and what commands it uses. To obtain the listing, create your program such that it repeatedly issues the interface read function to the MM3000 until the MM3000 sends the word END.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
CM — create macro
EM — execute macro
RM — erase macro

EXAMPLE
CM5;1PR100;2PR100 / *create macro #5*
LM / *list macros*
MACRO 5:1PR100;2PR1000 / *response*
END

USAGE ■ IMM □ PGM ■ MIP

SYNTAX
LP
LP nn
LP nn,mm
LP ,mm

PARAMETERS
Description
nn [int] — first program line number
mm [int] — last program line number
Range
nn — **1** to **number of program lines**
mm — **1** to **number of program lines**
Units none
Defaults
nn and mm missing: list all program lines
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to output a listing of the currently stored programs. During transmission, no other command should be sent to the controller.

RETURNS program listing

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
EP — enter program entry mode
% — quit program entry mode

EXAMPLE

```
LP                  / list all program lines
  0001 1PA1000      / controller returns
  0002 1WS100       / all program lines in memory
  0003 2PA–1000
  0004 2WS100
  0005 END

LP2,5               / list program lines 2 to 5
LP2                 / list program lines 2 to the end of program
LP,4                / list program lines 1 to 4
```

MF — disable motor power

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxMF**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command removes power from the motors. Note that the motor is turned-on again with the MO, PA, PR, or any other move commands.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **MO —** motor on

EXAMPLE **2MF** / *disable axis # 2 motor*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxMLnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn	—	type of limit
Range	**xx**	—	**1** to **4**
	nn	—	**+** or **–**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E02 - ILLEGAL PARAMETER
	nn missing:		defaults to +
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to move until it senses the travel limit. The parameter + or – sets the direction of motion.

Normally, when a travel limit switch is encountered during motion, the MM3000 stops all motion and generates an error message. However, with this command, reaching the travel limit is the desired function so other motions will not be stopped and an error message will not be generated.

CAUTION

It is recommended to set the velocity of the stage to not more than 10% of its maximum velocity when using this command to avoid damage.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
VA — set absolute velocity
AC — set acceleration

EXAMPLE

```
2ML-        // move axis # 2 to negative limit
1ML+        // move axis # 1 to positive limit
```

MO — enable motor power

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxMO**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command turns motor power on. It is the inverse of theMF command.

RETURNS none

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **MF —** motor off

EXAMPLE **2MO** / *turn power to axis 2 motor on*

USAGE ■ IMM ■ PGM ■ MIP

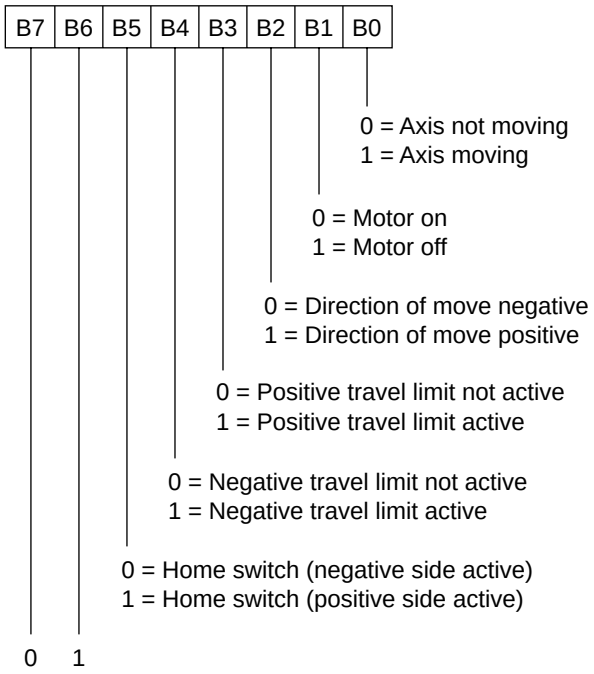
SYNTAX **xxMS**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command causes the MM3000 to respond with the axis information listed below. Each bit in the response byte represents a certain axis condition.

The response to this command is the ASCII representation of the bit pattern below. See Appendix for conversion from ASCII to binary.



RETURNS ASCII character representing the status byte

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **TS** — read system status

EXAMPLE

```
2MS          / read motor status byte for axis # 2
  A          / controller returns character A, ASCII charater 65. Converting
             / 65 to binary is 01000001, which means: axis 2 moving
             / negative, motor is on, no limits are active.
```

MV — move indefinitely

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxMVnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn	—	direction of move
Range	**xx**	—	**1** to **4**
	nn	—	**+** or **–**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to +
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command causes an indefinite move in the direction specified with the velocity entered with VA or VR commands. The move may be stopped by the AB, ST, and # commands or by the STOP ALL button. The move will stop automatically if a travel limit is reached. The velocity used is the last velocity entered. Note that the velocity may be changed on-the-fly.

CAUTION

It is recommended not move into hard limits of a stage with a velocity greater than 10% of maximum velocity of the stage.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
AC — set acceleration
VA — set absolute velocity
VR — set relative velocity

EXAMPLE

```
2MV+          / move axis # 2 in positive direction
1MV–          / move axis # 1 in negative direction
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxMZnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn	—	direction of move
Range	**xx**	—	**1** to **4**
	nn	—	**+** or **–**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to +
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to move until it senses the occurrence of an index pulse.

An index pulse is derived from a slot on an encoder disk. There is one index pulse per revolution. The MM3000 will rotate the motor until it senses this pulse. See Section 4 for details.

The velocity of the move can be set with VA and VR commands.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
VA — set absolute velocity
VR — set relative velocity

EXAMPLE

```
2MZ-        / move axis # 2 in negative direction until index pulse occurs
1MZ+        / move axis # 1 in positive direction until index pulse occurs
```

OA — set home search acceleration/deceleration

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxOAnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — acceleration value

Range

xx — **1** to **4**
nn — **250** to **1,000,000,000** **(DC Motor)**
nn — **15,000** to **450,000,000** **(Stepping Motor)**

Units

xx — none
nn — encoder or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the acceleration and deceleration portion of the velocity profile generator for HOME search.

For stepping motors, the OA parameter may be further modified with the SD command. See the SD Command for a complete explanation.

See Section 4.4.1 for an explanation of the velocity profile.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

OR — search for home
OL — set home search low speed
OH — set home search high speed

EXAMPLE **3OA50000** / *set home search acceleration to 50000 for axis #3*

set home search high velocity — OH

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxOHnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — velocity value

Range

xx — **1** to **4**
nn — **0** to **1,000,000,000** **(DC Motor)**
nn — **100** to **1,500,000** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets the desired value for absolute velocity used during HOME search. The HOME search algorithm loads the OH parameter first to quickly find the switch or floating origin then loads the OL parameter to move in slowly.

For stepping motors, the OH parameter may be further modified with the SD command. See the SD Command Section for a complete explanation.

For a detailed description of Home Search, see Section 4.4.3.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SD — speed divide
OL — set home search low speed
OA — set home search acceleration
OR — search for home

EXAMPLE **2OH2000** / *set home search high velocity to 2000 for axis #2*

OL — set home search low velocity

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxOLnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — low velocity value

Range

xx — **1** to **4**
nn — **0** to **1,000,000,000** **(DC Motor)**
nn — **100** to **1,500,000** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the desired value for absolute velocity used during HOME search. The HOME search algorithm loads the OH parameter first to quickly find the switch or floating origin then loads the OL parameter to move in slowly.

For stepping motors, the OL parameter may be further modified with the SD command. See the SD Command Section for a complete explanation.

For a detailed description of Home Search, see Section 4.4.3.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SD — speed divide
OH — set home search high speed
OA — set home search acceleration
OR — search for home

EXAMPLE **1OL5000** / *set home search low speed to 5000 for axis #1*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxOMnn**

PARAMETERS

Description	**xx** [int]		
	nn [int]		
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **2**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		zero assumed
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command selects the home search type without invoking the home search motion sequence (see OR command for more information on home search). The three home search types are FLOATING, SWITCH + INDEX and SWITCH only.

If nn = 0 and the front panel HOME search pushbutton is pressed, the axis will move to position +0. If nn = 1 and the front panel HOME search pushbutton is pressed, the axis moves to the home switch plus the occurrence of an index signal. If nn = 2 and the front panel HOME search pushbutton is pressed, the axis moves to only to the home switch.

The **nn** paramter is stored in non-volatile memory, but is overwritten by the OR command parameter or SEL HOME front panel menu.

To query the current OM setting simply append a question mark (?) to the command (i.e., OM ?).

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **OR** — home search

EXAMPLE

```
OM 1          / select switch + index home search mode
OM ?          / query current OM setting
   1          / response
```

OR — search for home

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxORnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	home search type
Range	**xx**	—	**1** to **4**
	nn	—	**0,1,** or **2**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		assumes 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command invokes the MM3000 HOME search algorithm which automatically seeks a predetermined home or origin.

The command OR0 directs the MM3000 to return the positioning device to the location where the position count is zero. This is referred to as the floating home. The floating home point is defined when the DH command is executed, which sets the position counter to zero.

The command OR1 directs the MM3000 to return the positioning device to the location of a origin (home) switch and the next occurrence of an index pulse.

The command OR2 directs the MM3000 to return the positioning device to the location of an origin switch only (i.e., does not look for index pulse).

For DC modules, a jumper has to be set to use this mode. See Appendix I for details

In either a floating or switch home search, the positioning device will travel with the speed and acceleration set with the OA, OH, and OL commands. The origin search algorithm is designed to reach the target position quickly and reduce mechanical backlash.

For a detailed description of Home Search, see Section 4.4.3.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

DH — define home
OA — set home search acceleration
OL — set home search low speed
OH — set home search high speed
OM — select home search mode

EXAMPLE

```
3OR1          / perform a home search (switch + index) on axis # 3
```

set overshoot value for floating home search — OV

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxOVnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	overshoot value
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **32,000**
Units	**xx**	—	none
	nn	—	encoder or steps
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command determines overshoot which will occur in floating HOME search procedure for eliminating the effect of mechanical backlash at the home position. It is necessary to make **nn** bigger than the backlash of the stage.

The units are encoder counts for DC motors, and encoder counts or steps for stepping motors, as set with the FM command.

The default value is 100.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

OR — initiate home search
OH — set home search high speed
OL — set home search low speed
OA — set home search acceleration

EXAMPLE

```
1OV500          / set home search overshoot to 500  for axis #1
```

PA — move to absolute position

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxPAnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	absolute position destination
Range	**xx**	—	**1** to **4**
	nn	—	**0** to ±**1,000,000,000 (DC Motor)**
	nn	—	**0** to ±**2,147,483,648 (Stepping Motor)**
Units	**xx**	—	none
	nn	—	encoder counts or steps
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command directs the MM3000 to initiate a move to the specified absolute position. The numerical parameter **nn** is treated as the target position relative to position zero defined by the DH command.

For DC Motors, the maximum displacement allowed is 1,000,000,000 encoder counts. If this number is exceeded, the MM3000 will not initiate the move and will generate an error.

DC motor modules can change position on the fly, i.e., a new target position can be entered before the last one was reached. The module will evaluate its state and proceed towards the last target position entered.

Stepping motor modules cannot change position on the fly, i.e., a PA command may not be issued to an axis while that axis is executing a previous move command. If this does occur, the MM3000 will discard the command and generate an E29 SYSTEM IS BUSY error message. Before issuing a PA command to a stepping motor in motion, send the WS command followed by the PA command, or wait for motion to be completed.

For overall system synchronization, use the TS command or interrupts to determine when a motion is complete and another one may be initiated. See FI command.

Note:
The MM3000 will not permit a motor to move to an absolute position beyond the soft travel limits, if soft limits are enabled. See SL and FM commands.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SE — simultaneous execution
AC — set acceleration
PR — move to relative position
ST — stop motion
VA — set velocity

EXAMPLE **1PA100;2PA100** / *move axis #1 and #2 simultaneously*

1PA100;WS;PA0 / *move axis #1, wait for stop, then move to zero*

1PA100;WP40;3PA100 / *move axis #1, wait for position 40, then move axis #3*
/ *to 100*

1PA100;WT1000;2PA0 / *move axis #1, wait 1 second, then move axis #2 to 0*

PE — power-on execution

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **PEn1;n2 ...**

PARAMETERS

Description
n1 [char] — MM3000 command
n2 [char] — MM3000 command

Range Valid commands consisting of a maximum of 20 characters

Units none

Defaults none

DESCRIPTION This command stores one or several commands for automatic execution at power-on of the MM3000.

A null string (i.e., PE with no command) will disable the function.
PE? lists the contents of the power-on execution programs.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE

```
PEEX2            / execute stored program #2 on power up. (program #2
                 / has to be created prior to this command)

PE1MO;1JY1       / turn motor power on axis 1 on and assign joystick axis 1
                 / to motor axis 1.

PE?              / list contents of power-on buffer
   1MO;1JY1      / response
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxPRnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	relative motion increment
Range	**nn**	—	**0** to ±**1,000,000,000** **(DC Motor)**
	nn	—	**0** to ±**8,388,607** **(Stepping Motor)**
Units	**xx**	—	none
	nn	—	encoder counts or steps
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command directs the MM3000 to make a move equal to the specified number of encoder counts or steps. The numerical parameter **nn** is treated as the number of encoder counts or steps to be taken from the present position in the specified direction.

For stepping motors, the displacement (number of steps) is calculated as follows:

NUMBER OF STEPS = (ENCODER RATIO) x (PR parameter)

The encoder ratio is set with the ER command. If the stepping motor axis was programmed for step pulse positioning units with the FM command, then the ER command specification is ignored and the encoder ratio automatically equals 1.

Stepping motor modules cannot change position “on the fly”. Before issuing a PR command to a stepping motor in motion, send the WS command followed by the PR command, or wait for motion complete.

DC motor modules can change position “on the fly”, i.e. a new relative position can be entered before the last one was reached. The module will evaluate its state and move relative to the position at the instant it received a new PR parameter.

For overall system synchronization, use the TS command or interrupts to determine when a motion is complete and another one may be initiated. See FI command and Appendix E for sample interrupt service programs.

Note:
The MM3000 will not permit a motor to move to a position beyond the soft travel limits set, if soft limits are enabled. See SL and FM commands.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

SE — simultaneous execution
AC — set acceleration
PA — move to absolute position
ST — stop motion
VA — set velocity

EXAMPLE **1PR100;2PR200** / *move axis #1 and #2 simultaneously*

1PR500;WS;PR250 / *move axis # 1, wait for stop, then move axis #1 again*

3PR500;WT1000;4PR50 / *move axis #3, wait 1 second, then move*
/ *axis #1 again*

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **QP**

PARAMETERS none

DESCRIPTION This command causes the MM3000 to exit program execution mode and re-enter command mode.

The MM3000 will quit the program when the command in progress is complete. For example, if a motion is in progress, it will not be stopped immediately. Instead, it will be carried to completion.

To stop motion immediately while in program execution mode, use theST, AB or # command.

RETURNS none

ERRORS none

REL. COMMANDS **EP** — enter programming mode
% — exit program entry mode

EXAMPLE

```
EX              / start program execution
 •
 •
 •
QP              / stop program execution
```

/QP — program delimiter

USAGE ☐ IMM ■ PGM ☐ MIP

SYNTAX **/QP**

PARAMETERS none

DESCRIPTION This instruction is used to separate contiguous programs in memory. It cannot be used in the command mode. When more than one program is required to be stored, /QP is used to separate them. Up to 99 programs may be stored. Programs are stored sequentially starting with 1. Each /QP instruction increments the program number by 1. The % instruction is used to exit program entry mode.

RETURNS none

ERRORS none

REL. COMMANDS
EP — enter programming mode
% — exit program entry mode

EXAMPLE

```
EP                  / enter program mode
1PA +10000          / program 1
1WS 1000
2PR 200
/QP                 / program delimiter
3PA +5000           / program 2
%                   / exit program mode
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RAnn**

PARAMETERS

Description	**nn** [int]	—	analog port number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**nn**	missing:	1 assumed
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command reads any of eight analog-to-digital converters available at the General Purpose I/O connector. Depending on both the reference voltage and input voltage to be converted the command returns a decimal value ranging from 0 to 1023. See Section 7 for a detailed description of the analog to digital converter.

RETURNS Decimal number representing converted voltage

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **RB —** read TTL I/O port

EXAMPLE
RA1 / *read value of analog port # 1*
1023 / *possible response*

RB — read I/O input

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RB**

PARAMETERS none

DESCRIPTION This command reads the logic levels of the 8 input/output bits available at the General Purpose I/O connector. See Appendix B for pinouts and electrical requirements. Before any bits are used, they should be defined as inputs with the BI command. The logic levels (1=high, 0=low) of the bits are reported in decimal representation.

See Appendix for conversion from decimal to binary.

Note that bits configured to be outputs with the BO command return their output state when RB is issued.

RETURNS Input byte value, 0 to 255 in ASCII format

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **BI —** define input bits

EXAMPLE

```
BI1,2,7,8          / define input bits
RB                 / read the state of the input bits
    129            / controller returns a value of 129,
                   / which converted to binary gives the status of the 8 input bits:
                     bit 8  bit 7  bit 6  bit 5  bit 4  bit 3  bit 2  bit 1
                       1      0      0      0      0      0      0      1
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RC**

PARAMETERS none

DESCRIPTION This command reports the type of motor module present at axis 1 through 4 in the MM3000.

RETURNS Axis configuration

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS none

EXAMPLE
RC / *read configuration*
1=stepper1.5 2=dc 3=dc 4=unused / *possible response*

RM — reset macros

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RM**

PARAMETERS none

DESCRIPTION This command erases all previously stored macro definitions. It has to be issued before a previously used macro number can be used to create a different macro.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
CM — create macro
LM — list macros
EM — execute macro

EXAMPLE
```
RM                    / reset macros
```

USAGE ■ IMM ☐ PGM ■ MIP

SYNTAX **RPnn**

PARAMETERS

Description	**nn** [int]	—	number of times to repeat command
Range	**nn**	—	**1** to **255**
Units	**nn**	—	none
Defaults	**nn**	missing:	repeat infinitely
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to repeat the execution of a command or a series of commands entered in command mode. The RP command is not permitted in stored programs — use DL and JL commands instead.

All commands to be repeated must be part of one string terminated by a carriage return (ASCII 13). The maximum number of characters is 80.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
DL — define label
JL — jump to label

EXAMPLE

```
1PA100;WS;PA0;WS;RP99    / repeat all commands prior to RP command
                         / 99 times. Note that commands are executed
                         / 100 times because first execution +99
                         / repeats = 100.
```

RQ — generate service request (SRQ)

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RQnn**

PARAMETERS

Description	**nn** [int]	—	interrupt number
Range	**nn**	—	**0** to **31**
Units	**nn**	—	none
Defaults	**nn**	missing:	0
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command generates an interrupt service request to the host computer. The parameter **nn** is used to identify the RQ command which generated the interrupt. Upon receiving the interrupt, the host computer interrupt service routine should perform an IEEE488 serial poll or send the TS command and read the response. If the interrupt was as a result of the RQ command, then bit 7 of the response is 1 and the lower five bits equal the parameter **nn**.

This command can be used to notify the host computer of the progress or flow of command execution in the MM3000.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **TS** — tell status

EXAMPLE
```
2PR200;WS;1PR100;WS;RQ   / generate interrupt when RQ command is
                         / encountered
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **RS**

PARAMETERS none

DESCRIPTION This command will cause the MM3000 to simulate a hardware reboot after about 2 seconds. Any commands in the command queue are erased and all position counters are set to 0 at this point.

RETURNS none

ERRORS none

REL. COMMANDS **#** — emergency stop

EXAMPLE **RS** / *reboot controller*

SB — set output bits

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **SBnn**

PARAMETERS

Description	**nn** [int]	—	I/O bit number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**nn**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the programmable bit(s) high. See Appendix B for pinouts and electrical requirements. All bits have to be defined as output with the BO command. This command is useful in synchronizing external devices to internal events (i.e., outputting a pulse when a motion is complete).

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
CB — clear I/O output port bits
TG — toggle I/O output port bits

EXAMPLE
```
SB1,3,8          / set output bits 1,3, 8 high, i.e., 5 volts
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxSDnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	speed divisor
Range	**xx**	—	**1** to **4**
	nn	—	**1** to **5000**
Units	**xx**	—	none
	nn	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION

This command divides all velocities by **nn** to obtain a lower effective stepping rate for subsequent moves.

Also, the acceleration set with the AC command and the OA command are divided by **nn** to obtain a slower effective acceleration for subsequent moves.

Normal operating velocity range of the stepping motor module is 100 to 1,500,000 steps/second. The SD parameter is used to divide this velocity so that a lower operating velocity can be achieved.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS

VA — set velocity
VB — set base velocity
VR — set relative velocity
AC — set acceleration
OH — set home search high velocity
OL — set home search low velocity
OA — set home search acceleration/deceleration
JA — set jog acceleration
JH — set jog high velocity
JW — set jog low velocity
UA — set acceleration in units
UV — set velocity in units

EXAMPLE

```
SD1       / speed range is 100 - 1,500,000 steps/sec. with a speed
          / resolution of 100 steps/sec. The achievable speeds are
          / (in ascending order) : 100, 200, 300, 400, ... 1,500,000
          / steps/sec.
SD5000    / speed range is 0.02 - 300 steps/sec. with a speed
          / resolution of 0.02 (100/5000) steps/sec. This is one pulse
          / every 50 seconds. The achievable speeds are 100, 200,
          / 300, 400, ... 1,500,000 steps/sec.
```

SE — start synchronized motion

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **SE**

PARAMETERS **none**

DESCRIPTION This command executes motion commands (e.g.,PA, UP) loaded previously for synchronized execution.

Prior to executing the SE command, axes to be synchronized for simultaneous execution must be assigned in advance with the SY command.

All axes are de-synchronized when (a) an SY command is received without a parameter, (b) a local jog, home or menu control is invoked, (c) an emergency stop or STOP ALL is invoked, or (d) a system reset occurs.

For most applications axes can be synchronized simply by sending multi-axis commands on the same command line separated by a semicolon. (e.g., 1PA1000;2PA-2000). However, there can be a commandinterpreting latency of about 1 or 2 milliseconds between the two commands. Using the SE and SY commands, this latency can be reduced to 10 μsec.

RETURNS none

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **SY** — set axis synchronization

EXAMPLE

```
SY 1,3          / set axis-1 and 3 to synchronization mode
1PA+100         / set axis-1 target move
3PA-200         / set axis-3 target move
SE              / start synchronized motion now
SY              / disable synchronization mode
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxSLnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — positive or negative travel limit

Range

xx — **1** to **4**
nn — ±**1** to ±**1,000,000,000** **(DC Motor)**
nn — ±**1** to ±**2,147,483,648** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets the soft travel limits as absolute positions relative to position zero. If subsequently position zero is redefined with the DH command, the soft limits adjust such that they retain their previous absolute positions. An example will best illustrate this point: the commands DH; SL+10000, SL–10000 issued in this order establish soft travel limits at absolute positions +10000 and –10000. Next, if the commands PR2000,DH are issued in this order, then the new soft limits become +8000 and –12000.

If the MM3000 is directed to make a move to a position beyond the soft limits, and the soft limits are enabled, it will not initiate the move and create an error message.

The FM command is used to enable/disable soft limits.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **FM —** enable/disable soft limits

EXAMPLE

```
1SL+200000      / set positive travel limit of axis #1 to 200000
1SL-100000      / set negative travel limit of axis #1 to 100000
   •
   •
   •
1FM02           / disable soft travel limits
```

SR — set RS232-C baud rate

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **SRnn**

PARAMETERS

Description	**nn** [int]	—	number representing a baud rate selection
Range	**nn**	—	**0** to **4**
Units	**nn**	—	none
Defaults	**nn**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the baud rate for the MM3000 RS-232C interface. However, other RS-232C parameters are fixed at 8 data bits, 1 stop bit, and no parity. Note that any changes in baud rate will take affect immediately.

BAUD RATE		PARAMETER
1200	———	0
2400	———	1
4800	———	2
9600	———	3 (default)
19200	———	4

Note:
Baud rate defaults to 9600 after system reset or power off/on cycle.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE **SR1** / *set baud rate to 2400 baud*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxST**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command stops a motion using the programmed deceleration (see AC command).

If the MM3000 is executing a wait command, for example, WS, WP, or WT when this command is issued, it will be queued and only executed when all the previous commands are done.

Use the # command to stop motion immediately at any time.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
AB — abort motion
**—** emergency stop all axes

EXAMPLE

```
2PA 10000        / move axis 2 to position 10000
2ST              / stop motion when ST is received
```

SV — set variable value

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **SVVnn = mm**

PARAMETERS

Description

nn [int] — variable number
mm [int] — constant or formula

Range

nn — **0** to **9**
mm — **–1,000,000,000** to **1,000,000,000**

Units

nn — none
mm — none

Defaults

nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER
mm missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command sets a value for one of ten possible variables which can be used as parameters in all motion commands. The expression can be a constant or a simple two-operant operation.

All variables are initially 0 unless set otherwise. Variable Vnn can be used as an argument for other commands (see example).

Some valid expressions are:

```
SV V0=1000
SV V1=V0+1000
SV V1=V1*V0
SV V2=V1/V0
```

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE

```
SVV0=100          / initialize variable 0 to 100
VA100;PA1000      / move axis 2 at velocity of 100 to position 1000
DLA;SVV0=V0+100;VAV0;WT100;JLA10    / increment velocity every
                                    / 100 milliseconds
SVV3=200
DLA;SVV0=V0+100;PRV0;WS;JLA10       / increment successive
                                    / displacements by 100 units
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **SY**xx_1, xx_2, xx_3, xx_4

PARAMETERS

Description	**xx** [int]	—	axis number
Range	$xx_{1–4}$	—	**1** to **4**
Units	$xx_{1–4}$	—	none
Defaults	**xx**	missing:	defaults to 0
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to assign axes to synchronized motion command execution mode. Axes in this mode will not execute motion commands (e.g., PA, UP) until the SE (start motion synchronization) command is received.

All axes are de-synchronized when (a) an SY command is received without a parameter, (b) a local jog, home or menu control is invoked, (c) an emergency stop or STOP ALL is invoked, or (d) a system reset occurs.

For most applications, axes can be synchronized simply by sending multi-axis commands on the same command line separated by a semicolon (e.g., 1PA1000;2PA-2000). However, there can be a commandinterpreting latency of about 1 or 2 milliseconds between the two commands. Using the SE and SY commands, this latency can be reduced to 10 μsec.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **SE** — set axis synchronization

EXAMPLE

```
SY 1,3          / set axis-1 and 3 to synchronization mode
1PA+100         / set axis-1 target move
3PA-200         / set axis-3 target move
SE              / start synchronized motion now
SY              / disable synchronization mode
```

TB — tell message buffer

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **TB**

PARAMETERS none

DESCRIPTION This command reports the contents of the MM3000 error message buffer. Whenever a command syntax or parameter error is detected or a motor error is encountered, the MM3000 transmits the corresponding message to the error buffer. The error buffer can then be read with the TB command.

Note that the FO command may be used to shorten the response length by suppressing error description characters.

For faster responses use the TE command which outputs the error code in the form of an ASCII character.

The TB command clears the error flag in the TS command response byte.

RETURNS Error message.

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
TE — report error number
FO — format response
TS — report status
FI — format interrupt

EXAMPLE
```
TB                      / report buffer contents
E01 BAD COMMAND         / response indicates that a bad command
                        / was sent previously
```

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **TE**

PARAMETERS none

DESCRIPTION This command reports the error code generated by the last error encountered. The controller returns the content of the error buffer in the form of an ASCII character. The ASCII character can be converted to binary with the table in the Appendix. Bit 6 and 7 of the converted ASCII character are always set to 1 and 0, respectively. See example.

Note:
Reading the buffer resets it.

RETURNS Error code

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
TB — report error buffer contents
TS — report status
FI — format interrupt

EXAMPLE

```
TE                  / report error buffer contents
   B                / controller returns B, which is ASCII 66.  66 is binary
                    / 01000010. Since bit 6 is always 1 and bit 7 always 0,they
                    / can be ignored.  That leaves us with binary 00000010,
                    / which is 2 decimal → E02 - ILLEGAL PARAMETER
```

TF — tell filter parameters DC Motor

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTF**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command reports the last PID filter parameters received. If any new PID parameters have been issued with either the KP, KD, KI, IL or DS but the UF command has not yet been received, then the "filters not updated" message will appear along with the parameters. This means that the parameters displayed have not yet been loaded into working PID registers.

RETURNS **KP=nn$_1$ KD=nn$_2$ KI=nn$_3$ IL=nn$_4$ DS=nn$_5$**

where: **nn$_1$** = proportional gain factor
nn$_2$ = derivative gain factor
nn$_3$ = integral gain factor
nn$_4$ = integral limit
nn$_5$ = derivative sample time

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
KP — set proportional gain
KD — set derivative gain
KI — set integral gain
IL — set integral limit
TL — tell limit (reports also the following error)

EXAMPLE
2TF / *read filter parameters of axis # 2*
KD=100 KD=200 KI=100 IL=50 DS=0 / *possible response*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **TGnn**

PARAMETERS

Description	**nn** [int]	—	I/O bit number
Range	**nn**	—	**1** to **8**
Units	**nn**	—	none
Defaults	**xx**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command toggles output bits of the GPIO port. Prior to using a bit, it must be defined as an output with the BO command. The pulse polarity depends on the logic level of the output bit just before the TG command is issued. The TG command changes the logic level of the toggle bit twice to create the pulse. The pulse width is typically less than 5 micro-seconds making it suitable for external edge triggering.

See Appendix B for pinouts and electrical requirements.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
CB — clear I/O output port bits
SB — set I/O output port bits

EXAMPLE
```
BO1,3,8          / declare bits 1, 3, 8 as outputs
TG1,3,8          / toggles output bits 1, 3, 8
```

TL — tell limit conditions

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTL**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command reports the current soft travel limit parameters in use for the specified axis. In addition, for DC motor modules only, this command also reports the current DC motor following error threshold previously set with the FE command.

Note:
The soft travel limit feature is enabled and disabled with theFM command.

RETURNS **SL=+nn$_1$ SL=-nn$_2$ FE=nn$_3$**
where: **nn$_1$** = positive soft travel limit
nn$_2$ = negative soft travel limit
nn$_3$ = following error setting, if DC motor module

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
SL — set soft limits
FM — enable / disable soft limits

EXAMPLE
```
1TL                    / reportlimit settings on axis #1
SL=+10000  SL=-100000  FE=5000    / typical response of DC module
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **TM**

PARAMETERS none

DESCRIPTION This command reports the non-volatile program memory usage. When a program (source code) is downloaded to the MM3000, it is stored in non-volatile program memory and consumes n number of bytes. When the program is compiled, the total bytes consumed = source code+ object code. If the overall program requires more bytes than available, the MM3000 will not execute the program.

RETURNS Amount of memory used and amount of memory available.

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS none

EXAMPLE
TM / *tell memory usage*
100 BYTES USED 24900 BYTES FREE / *typical response*

TP — tell actual position

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTP**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command directs the MM3000 to report the current position of the axis specified with **xx**.

Stepping modules respond either in encoder counts (COUNTS) or step pulses (STEPS). The choice is made with the FM command.

For DC motors, the units of the response is always encoder counts (COUNTS).

RETURNS Position number for the specified axis

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
TPI — tell position in step units
TPE — tell position in encoder counts

EXAMPLE

```
3TP                 / read  position on axis # 3
    1000 COUNTS     / response for encoder position tracking
1TP                 / read  position on axis # 1
    1000 STEPS      / response for stepping motor without encoder
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTPE**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to report the current position inencoder counts, regardless of the positioning units set with theFM command.

This command enables you to obtain encoder position data when the position units are set to steps.

The TP command reports position in terms of encoder counts or steps. The selection is done with the FM command.

RETURNS Position in encoder counts for the specified axis

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
TPI — tell position in step units
TP — tell position in terms of positioning units

EXAMPLE
```
3TPE                    / read encoder position on axis # 3
    1000 COUNTS         / response for encoder position tracking
```

TPI — tell position in motor step units — Stepping Motor

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTPI**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E01 - BAD COMMAND

DESCRIPTION This command directs the MM3000 to report the current position in step counts, regardless of the positioning units set with the FM command.

This command enables you to obtain motor steps position data when the position units are set to encoder counts.

The TP command reports position in terms of encoder counts or steps. The selection is done with the FM command.

RETURNS Position number for the specified axis

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
TPE — read position in units of encoder counts
TP — read position in terms of positioning units

EXAMPLE
3TPI / *read position on axis # 3 in units of motor steps*
1000 STEPS / *response*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTRnn,mm**

PARAMETERS

Description

xx	[int]	—	axis number
nn	[int]	—	time interval
mm	[int]	—	number of samples

Range

xx		—	**1** to **4**
nn		—	**1** to **10,000**
mm		—	**1** to **1000**

Units

xx		—	none
nn		—	100 microseconds
mm		—	none

Defaults

xx	missing:	last axis specified with the previous command
	out of range:	E01 - BAD COMMAND
nn	missing:	E02 - ILLEGAL PARAMETER
	out of range:	E02 - ILLEGAL PARAMETER
mm	missing:	E02 - ILLEGAL PARAMETER
	out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION

The TR instruction initializes motion tracing mode for a specified axis. The parameter **nn** multiplied by 100 micro-seconds determines the time between samples and **mm** is the total number of samples. Upon instruction execution, the MM3000 will sample the motion trace of both the desired position and the actual position and store it into a trace buffer. TheTT instruction is used to retrieve data from the trace buffer.

Note:
The TR instruction without parameters will **turn off** tracing mode.

Note:
All previously stored programs are erased when this command is used.

Motion tracing is a very useful tool in the PID parameters tuning of DC motors. High servo performance can be achieved by measuring and minimizing the overshoot, setting time and ringing.

See Section 4 and 5 for details.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **TT —** read trace data

EXAMPLE

```
1TR10,3000      / record axis #1 motion at 1 millisecond (10 x 100 usec)
                / intervals; obtain 3000 samples
```

TS — tell controller status

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **TS**

PARAMETERS none

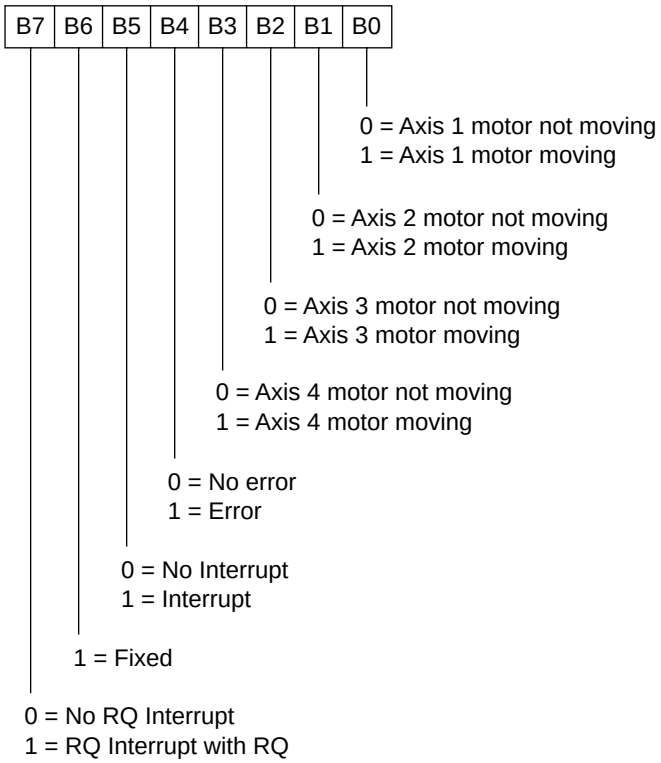
DESCRIPTION This command reads the controllers status byte. It returns a single byte:

The interrupt bit in the response byte is automatically reset after aTS command is executed.

The byte returned is in the form of an ASCII character. Converting the ASCII byte to binary will give the status bit values that can be interpreted with the diagram below.

Note:
See Appendix for a ASCII to binary conversion table.

Bit 7 is normally fixed at 0, unless an RQ command was executed previously. The RQ command will set bit 7 to 1. Bit 7 is automatically reset after aTS command is executed.



RETURNS ASCII character representing the status byte

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **MS —** read motor status

EXAMPLE

```
TS          / read controller status byte
   A        / response is ASCII 65 = 0100 0001 binary, implies axis #1
            / moving, axis #2, #3, and #4 are stationary, no error, and
            / no interrupt
```

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxTT**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to output the data in the trace buffer. If trace mode has been enabled with the TR command, the response to the command will include both actual positions and desired positions which have been sampled and stored during the last move.

Every 2(i)th data is actual position and every 2(i+1)th is the desired position at (i)th sample time. Like all other multi-line responses from the MM3000, the output will be terminated by the string “END”.

Note:
While the MM3000 is reporting trace data, all front panel displays will show the message “WORKING”.

RETURNS Theoretical and actual positions. See example.

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS **TR —** set motion mode trace

EXAMPLE

```
1TR10,1000        / set trace period to 1ms and 1000 samples
1PR2000;WS        / initiate motion and wait for stop
TT                / read recorded position data
   +0             / actual position at 0ms, 1st sample
   +0             / theoretical  position at 0ms, 1st sample
   +1             / actual position at 1ms, 2nd sample
   +2             / theoretical  position at 1ms, 2nd sample
   •
   •
   •
   +1001          / actual position at 999ms, 1000th sample
   +1000          / theoretical  position at 999ms, 1000th sample
```

TV — tell desired velocity

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxTV**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command reports the desired velocity requested with the VA or VR commands. Note that regardless of the FM command setting, DC motor modules will always respond in terms of counts/sec while stepping motor modules also includes the base velocity set with the VB command and the speed divide factor set by the SD command.

RETURNS Desired velocity

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS
VA — set absolute velocity
FR — set relative velocity
DP — read desired position

EXAMPLE

```
2TV                     / read desired velocity on axis #2
    5000 COUNTS/SEC     / dc motor response
3TV                     / read desired velocuty on axis #3
    100-20000 STEPS/SEC / stepping motor response
                        / 100 is base velocity (see VB command)
```

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxTYnn**

PARAMETERS

Description	**xx** [int]		
	nn [int]		
Range	**xx**	—	**1** to **4**
	nn	—	**1** to **9**
Units	**xx**	—	none
	nn	—	none
Default	**xx** missing:		last axis specified with previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets all motion (e.g., velocity, acceleration) and motion related (e.g., PID, encoder ratio) parameters to appropriate values suitable for unloaded Newport stages.

The TY command sets the following parameters:

FE, KD, KP, KI, IL, DS, VA, AC, OH, OL, OA, JH, JW, JA, OM, CO, BA, US, FM, OV, ER, VB, SD

Please refer to TYPE cross reference in Appendix C.

The purpose of this command is to facilitate quick system set-up. If necessary, parameters can be optimized for specific applications requirements (e.g., load, speed) and/or stage configuration (e.g., XY, XYZ) using programs like PROFILE.

The **nn** parameter is stored in non-volatile, but is overwritten by theXX command or SEL TYPE front panel menu. To query the currentTY setting, simply append a question mark to the command (e.g.,TY ?).

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS none

EXAMPLE

```
TY?          / query current TY setting
  0          / MM3000 response (memory purged. TY not defined)
TY 8         / select stage/motor TYPE # 8 (see Appendix C)
```

UA — set acceleration in units

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxUAnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [floating]	—	velocity
Range	**xx**	—	**1** to **4**
	nn	—	**1,000,000,000**
Units	**xx**	—	none
	nn	—	um, mm, in, mil, deg, mdeg, mrad, urad
Default	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND
	nn	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to set the acceleration used for move commands UR, UP.

The acceleration is in terms of units/sec^2, where units has to be previously selected with the UU command.

A new acceleration value may NOT be sent while the move is in progress. Acceleration can be changed when the motor is idle.

Note that the units acceleration parameter is NOT permitted outside the equivalent range of 250–1,000,000,000 counts/sec^2 for DC motor stages or 15,000 to 450,000,000 steps/sec^2 for stepper stages.

UA? reports the current setting.

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E56 — USER UNIT NOT DEFINED

REL. COMMANDS
US — Define Stage Reolution
UU — Select Positioning Units
UV — Set Velocity (in positioning units)
UP — Move To Absolute (in positioning units)
UR — Move Relative (in positioning units)
UW — Wait For Position (in positioning units)

EXAMPLE

```
1US 0.1um       / define axis #1 resolution as 0.1 micron
1UU mm          / select 'millimeter' positioning units
1UV 2.3         / set velocity to 2.3 mm/second
1UA 25.1        / set acceleration to 25.1 mm/sec^2
1UP 4.5         / move to absolute position 4.5mm
1UA ?           / report axis #1 target acceleration
   25.1 mm/sec  / MM3000 response
2US 0.001 deg   / define axis #2 resolution as 0.001 deg
2UU deg         / select 'degree' positioning units for axis #2
UV4.2           / set axis #2 velocity to 4.2 deg/second
```

```
2UA 32.2          / set acceleration to 32.2 deg/sec^2
2UR30.5           / move axis #2 relative position 30.5 degrees
2UA?              / report axis #2 target acceleration
    2.2 deg/sec   / MM3000 response
3UV ?             / report axis #3 target acceleration
    ???           / MM3000 response  (units not set)
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxUF**

PARAMETERS

Description	**xx** [int]	—	axis number
Range	**xx**	—	**1** to **4**
Units	**xx**	—	none
Defaults	**xx**	missing:	last axis specified with the previous command
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION This command makes active the latest PID parameters entered. Any new value for KP, KI, KD, IL and DS are not being used in the PID loop calculation until the UF command is received. This assures that the parameters are loaded simultaneously and without problems.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
TF — tell filter
IL — integration limit
KD — set derivative gain factor
KI — set integral gain factor
KP — set proportional gain factor
DS — derivative sample time

EXAMPLE

```
3KP100          / set proportional gain factor of  axis # 3 to 100
3KD200          / set derivative gain factor of  axis # 3 to 500
   •
   •
   •
3UF             / update servo loop of axis # 3 with the new parameters
```

move to absolute position in units — UP

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxUPnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [floating]	—	absolute position
Range	**xx**	—	**1** to **4**
	nn	—	±**1,000,000,000**
Units	**xx**	—	none
	nn	—	um, mm, in, mil, deg, mdeg, mrad, or urad
Default	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND
	nn	missing:	zero assumed
		out of range:	E02 - ILLEGAL PARAMETER or E24 - PARAMETER OUT OF RANGE

DESCRIPTION

This command directs the MM3000 to initiate a absolute move to an absolute position in units. The numerical parameter **nn** is treated as the target position relative to position zero.

The displacement is in terms of units, where units must be selected with the UU command.

For DC motors, a new target position may be sent while another move on the same axis is still in progress. If necessary, the controller will automatically decelerate, reverse direction and accelerate toward the new target position.

For stepper motors, a new target position may NOT be transmitted unless the axis has stopped. Positioning can be based on either step pulse output or encoder feedback. If encoder feedback is chosen, clear FM command bit-0 and appropriately set encoder-to-step ratio with ER command. Other,wise, set FM command bit-0 for step pulse positioning.

Note that the units position parameter is NOT perimitted outside of the equivalent range of ±1,000,000,000 counts for DC motor stages or ±16,777,215 steps for stepper stages.

UP? reports the desired position.

Note that the minimum commanded position is equal to the resolution set with the US command.

RETURNS none or current position (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E29 — SYSTEM IS BUSY
E36 - 42— HARD TRAVEL LIMIT
E43 - 50— SOFT TRAVEL LIMIT
E56 — USER UNIT NOT DEFINED

REL. COMMANDS

US — Define Stage Reolution
UU — Select Positioning Units
UV — Set Velocity (in positioning units)
UA — Set Acceleration (in positioning units)
UR — Move Relative (in positioning units)
UW — Wait For Position (in positioning units)

EXAMPLE

```
1US 0.1um       / define axis #1 resolution as 0.1 micron
1UU mm          / select millimeter positioning units
1UV 2.3         / set velocity to 2.3 mm/second
1UA 25.1        / set acceleration to 25.1 mm/sec²
1UP 4.5; 1WS    / move to absolute position 4.5mm
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxUPnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [floating]	—	absolute position
Range	**xx**	—	**1** to **4**
	nn	—	±**1,000,000,000**
Units	**xx**	—	none
	nn	—	um, mm, in, mil, deg, mdeg, mrad, or urad
Default	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND
	nn	missing:	zero assumed
		out of range:	E02 - ILLEGAL PARAMETER or E24 - PARAMETER OUT OF RANGE

DESCRIPTION

This command directs the MM3000 to initiate a relative move in units. The numerical parameter **nn** is treated as the relative displacement to the current position.

The displacement is in terms of units, where units must be selected with the UU command.

For DC motors, a new target position may be sent while another move on the same axis is still in progress. If necessary, the controller will automatically decelerate, reverse direction and accelerate toward the new target position. Positioning is always based on encoder feedback.

For stepper motors, a new displacement command may NOT be transmitted unless the axis has stopped moving.

For stepper motors, the positioning can be based on either step pulse output or encoder feedback. If encoder feedback is choosen, clear FM command bit-0 and appropriately set encoder-to-step ratio with ER command. Otherwise, set FM command bit-0 for step pulse positioning.

Note that the units position parameter is NOT perimitted outside of the equivalent range of ±1,000,000,000 counts for DC motor stages or ±16,777,215 steps for stepper stages.

UR? reports the desired relative position.

Note that the minimum commanded position is equal to the resolution set with the US command.

RETURNS none or current position (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E29 — SYSTEM IS BUSY
E36 - 42 — HARD TRAVEL LIMIT
E43 - 50 — SOFT TRAVEL LIMIT
E56 — USER UNIT NOT DEFINED

REL. COMMANDS

US — Define Stage Reolution
UU — Select Positioning Units
UV — Set Velocity (in positioning units)
UA — Set Acceleration (in positioning units)
UW — Wait For Position (in positioning units)

EXAMPLE

```
2DH              / reset axis #2 position counter (define home)
2US 0.001 deg    / define axis #2 resolution as 0.001 deg
2UU deg          / select degree positioning units for axis #2
2UV 4.2          / set axis #2 velocity to 4.2 deg/second
2UA 32.2         / set acceleration to 32.2 mm/sec²
2UR -30.5; 2WS   / move axis #2 relative -30.5 degrees
```

define stage resolution — US

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxUSnnaa**

PARAMETERS

Description

xx [int]	—	axis number
nn [floating]	—	stage resolution
ss [string]	—	unit

Range

xx	—	**1** to **4**
nn	—	**100.0** to **0.000001**
ss	—	um, deg

Units

xx	—	none
nn	—	micro meters (um) or degrees (deg)

Default

xx	missing:	last axis specified with previous command
	out of range:	E01 - BAD COMMAND
nn	missing:	E02 ILLEGAL PARAMETER
	out of range:	E02 ILLEGAL PARAMETER
aa	missing:	E02 ILLEGAL PARAMETER
	out of range:	E02 ILLEGAL PARAMETER

DESCRIPTION

This command is used to define a stage resolution for the specified axis. The numerical parameter **nn** is the smallest incremental displacement for that axis.

For DC motor stages, the resolution is equal to the encoder resolution.

For stepping motor stages, the resolution can be equal to either the step resolution or encoder resolution. If you use the encoder resolution, clear FM command bit-0 and appropriately set encoder-to-step ratio with ER command. Otherwise, set FM command bit-0 for step resolution.

Note:
Stored programs with unit commands must be recompiled with CP if this command changes resolution parameters.

Note:
All linear travel stage resolution must be defined in terms of microns (um). All rotary travel stage resolution must be defined in terms of degrees (deg).

US? reports the current resolution setting.

RETURNS none or current setting (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT

REL. COMMANDS

UU — Select Positioning Units
UV — Set Velocity (in positioning units)
UA — Set Acceleration (in positioning units)
UP — Move To Absolute (in positioning units)
UR — Move Relative (in positioning units)
UW — Wait For Position (in positioning units)

EXAMPLE

```
1US 0.1um       / define axis #1 resolution as 0.1 micron
1UU mm          / select millimeter positioning units
```

UU — select positioning unit

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxUUaa**

PARAMETERS

Description

xx [int] — axis number
aa [string] — unit

Range

xx — **1** to **4**
aa — um, mm, in, mil, deg, mdeg, mrad, urad

Units

xx — none
aa — none

Default

xx missing: last axis specified with previous command
out of range: E01 - BAD COMMAND
aa missing: Disables units feature
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command allows the user to select from up to eight (4 linear and 4 rotary) positioning units per axis.

Linear stages can be programmed in microns (um), millimeters (mm), inches (in), and milli-inches (mil). Rotary stages can be programmed in degrees (deg), millidegrees (mdeg), milliradiants (mrad), and microradiants (urad).

Note that the stage resolution must be defined with theUS command prior to selecting a positioning unit.

When a unit is selected, the corresponding front panel display (optional) automatically shows stage position in programmed units.

If this command is recieved without a unit parameter, the user defined positioning units feature is disabled.

Note:
Stored programs with unit commands must be recompiled with theCP after the UU command is used.

UU? reports current unit setting.

RETURNS none or current setting (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E55 — STAGE RESOLUTION NOT DEFINED
E57 — UNIT/STAGE MISMATCH

REL. COMMANDS

US — Define Stage Resolution
UV — Set Velocity (in positioning units)
UA — Set Acceleration (in positioning units)
UP — Move To Absolute (in positioning units)
UR — Move Relative (in positioning units)
UW — Wait For Position (in positioning units)

EXAMPLE

```
1US 0.1um       / define axis #1 resolution as 0.1 micron
1UU mil         / select milli inches positioning units
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxUVnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [floating]	—	velocity
Range	**xx**	—	**1** to **4**
	nn	—	**1,500,000**
Units	**xx**	—	none
	nn	—	um, mm, in, mil, deg, mdeg, mrad, or urad
Default	**xx**	missing:	last axis specified with previous command
		out of range:	E01 - BAD COMMAND
	nn	missing:	E02 - ILLEGAL PARAMETER or E24 - PARAMETER OUT OF RANGE
		out of range:	E02 ILLEGAL PARAMETER

DESCRIPTION This command is used to set the velocity in units for the next move and all subsequent moves until changed to a new value.

The velocity is in terms of units/second, where units was previously selected with the UU command.

A new velocity value may be sent while the move is in progress. The controller automatically accelerates or decelerates to the new velocity.

Note:
The units velocity range may not exceed the equivalent range of 1,000,000 counts/second for DC motor stages or 100 to 1,500,000 steps/second for stepper stages.

UV? returns current setting.

RETURNS none or current setting (see example)

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E56 — USER UNIT NOT DEFINED

REL. COMMANDS
US — Define Stage Reolution
UU — Select Positioning Units
UA — Set Acceleration (in positioning units)
UP — Move To Absolute (in positioning units)
UR — Move Relative (in positioning units)
UW — Wait For Position (in positioning units)
VB — Set Base Velocity

EXAMPLE

```
1US 0.1um       / define axis #1 resolution as 0.1 micron
1UU mm          / select millimeter positioning units
1UV 2.3         / set velocity to 2.3 mm/second
1UA 25.1        / set acceleration to 25.1 mm/sec²
```

UW — wait for position crossing in units

USAGE ■ IMM ■ PGM □ MIP

SYNTAX **xxUWnn**

PARAMETERS

Description

xx [int] — axis number
nn [floating] — absolute position

Range

xx — **1** to **4**
nn — **±1,000,000,000**

Units

xx — none
nn — um, mm, in, mil, deg, mdeg, mrad, or urad

Default

xx missing: last axis specified with previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 ILLEGAL PARAMETER

DESCRIPTION

This command directs the MM3000 to wait until the absolute position **nn** is crossed before processing the next command. This command is useful for position synchronization.

The position parameter **nn** is in terms of units, where units has to be previously selected with the UU command.

For DC motors, positioning is always based on encoder feedback.

For stepper motors, the positioning can be based on either step pulse output or encoder feedback. If encoder feedback is choosen, clear FM command bit-0 and appropriately set encoder-to-step ratio with ER command. Otherwise, set FM command bit-0 for step pulse positioning.

Note that the units position parameter is NOT perimitted outside of the equivalent range of ±1,000,000,000 counts for DC motor stages or ±16,777,215 steps for stepper stages.

Note:
While the MM3000 is executing this command, all front panel displays show the message: “WORKING”.

RETURNS none or current position (see example)

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E03 — COMMUNICATION TIMEOUT
E56 — USER UNIT NOT DEFINED

REL. COMMANDS

US — Define Stage Reolution
UU — Select Positioning Units
UV — Set Velocity (in positioning units)
UA — Set Acceleration (in positioning units)
UR — Move Relative (in positioning units)
UP — Move To Absolute Position (in positioning units)

EXAMPLE

```
1DH          / reset axis #1 position counter
1US 0.1um    / define axis #1 resolution as 0.1 micron
1UU mm       / select millimeter positioning units
1UV 2.3      / set velocity to 2.3 mm/second
1UA 25.1     / set acceleration to 25.1 mm/sec²
1UP +2.5     / move axis #1 to absolute position 2.5mm
1UW+1.3      / wait for axis #1 to cross 1.3mm then...
1UV 1.2      / reduce axis #1 velocity to 1.2mm/sec
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxVAnn**

PARAMETERS

Description	**xx** [int]	—	axis number	
	nn [int]	—	velocity value	
Range	**xx**	—	**1** to **4**	
	nn	—	**0** to **1,000,000,000**	**(DC Motor)**
	nn	—	**100** to **1,500,000**	**(Stepping Motor)**
Units	**xx**	—	none	
	nn	—	encoder counts/sec.	**(DC Motor)**
			steps/sec.	**(Stepping Motor)**
Defaults	**xx** missing:		last axis specified with the previous command	
	out of range:		E01 - BAD COMMAND	
	nn missing:		defaults to 0	
	out of range:		E02 - ILLEGAL PARAMETER	

DESCRIPTION This command sets the velocity for the next move and all subsequent moves until changed to a new value. For a series of moves at the same velocity, it is not necessary to repeatedly issue the VA command.

For stepping motors, the velocity set with this command is always in terms of steps/second, irrespective of the FM command setting. For DC motors, the velocity is in terms of encoder counts/second.

A new velocity value may be sent while a move is in progress. The MM3000 will automatically accelerate or decelerate to the new velocity.

For stepping motors, to obtain an operating velocity less than 100 steps/second, use the SD command to divide the programmed velocity.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
SD — speed divide
AC — set acceleration
PA — execute an absolute motion
PR — execute a relative motion
DV — read desired velocity

EXAMPLE
```
4VA50000          / set velocity for axis #4 to 50000
DV                / read desired velocity
  50000 COUNTS/SEC    / typical response for DC module
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxVBnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	velocity value
Range	**xx**	—	**1** to **4**
	nn	—	**100** to **velocity set with VA and or VR commands**
Units	**xx**	—	none
	nn	—	steps/sec.
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command sets the start/stop velocity for stepping motors only. The allowed start/stop velocity must be less than or equal to the velocity set with the VA and VR commands.

To obtain a base velocity less than 100 steps/second, use theSD command to divide the programmed velocity.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
AC — set acceleration
PA — execute an absolute motion
PR — execute a relative motion

EXAMPLE **2VB4000** / *set start/stop velocity for axis #2 to 4000 steps/sec*

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **VE**

PARAMETERS none

DESCRIPTION This command reports the revision level of the MM3000 firmware.

RETURNS **Newport Corporation MM3000 Version x.y**

where: **x.y** = version and release number

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE **VE** / *read version*
Newport Corp. MM3000 Version x.y/ *typical response*

VR — set relative velocity

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxVRnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — velocity increment / decrement value

Range

xx — **1** to **4**
nn — **0** to ±**1,000,000** **(DC Motor)**
nn — **0** to ±**1,500,000** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps/sec.

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: defaults to 0
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command is used to increment or decrement the present operating velocity. The new velocity is calculated as:

new velocity = last velocity + **nn**

The new velocity must remain positive and within the minimum/maximum range for the motor type.

For DC motors:
Minimum Velocity = 0 encoder count/second
Maximum Velocity = 1,000,000,000 encoder counts/second

For Stepping motors:
Minimum Velocity = 100 steps/second
Maximum Velocity = 1,500,000 steps/second

For stepping motors, the velocity is always in terms of steps/second, irrespective of the FM command setting.

For DC motors, the velocity is in terms of encoder counts/second.

A new velocity value may be sent while a move is in progress. The MM3000 will automatically accelerate or decelerate to the new velocity.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **VA —** set absolute velocity

EXAMPLE

```
2VA1000          / set absolute velocity of axis 2 to 1000
2VR-500          / decrement axis #2 velocity by 500
2DV              / read desired velocity
   500 COUNTS/SEC      / typical response for DC Motor
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxVSnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	velocity value in terms of sample time
Range	**xx**	—	**1** to **4**
	nn	—	**1** to **16,777,778**
Units	**xx**	—	none
	nn	—	none.
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command allows the user to set a value for absolute velocity with higher resolution than possible with the VA command. The resulting velocity value is calculated as:

$$\text{velocity} = \frac{\text{nn}}{256 \times 10^{-6} \times 65536} \text{ counts/sec}$$

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E05 — COMMAND/MODULE MISMATCH

REL. COMMANDS
VA — set absoute velocity
VR — set relative velocity

EXAMPLE
```
2VS100          / set axis #2 velocity to 6 counts/second
```

WA — wait for all axes to stop

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxWAnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — wait time (delay)

Range

xx — **1** to **4**
nn — **0** to **32767**

Units

xx — none
nn — milliseconds

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: 0
out of range: E02 - ILLEGAL PARAMETER
floating point: decimal part truncated

DESCRIPTION This command causes the controller to pause for a specified amount of time. This means that the controller will wait **nn** milliseconds before executing the next command.

Note:
Even though this command can be executed in immediate mode, its real value is as a flow control instruction inside programs.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
WT — wait
WS — wait for stop
WP — wait for position

EXAMPLE

```
1PA100;2PA200;WA100;1PA0  / move axis 1 to position 100, axis 2 to
                          / position 200, wait for both axes to stop
                          / and then move axis 1 to position 0.
```

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **WBnn,mm**

PARAMETERS

Description	**nn** [int]	—	input bit number
	mm [char]	—	logical level: H(igh) or L(ow)
Range	**nn**	—	**1** to **8**
	mm	—	**H** or **L**
Units	**nn**	—	none
	mm	—	none
Defaults	**nn** missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER
	mm missing:		E02 - ILLEGAL PARAMETER
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command causes the MM3000 to wait for the specified bitsto attain the specified logic level (high/low) and then proceed to execute the next command.

This command can be used to synchronize command execution with external events.

RETURNS none

ERRORS E02 — ILLEGAL PARAMETER

REL. COMMANDS

BI	**—**	set input bits
IF / THEN	**—**	if input bit high / low ... then
WHILE / WEND	**—**	do while input bit high / low

EXAMPLE

```
BI1,2          / set I/O bit #1 and #2 as inputs
WB1L,2H        / wait for bit #1 low (0 volts) and bit #2 high (+5 volts)
1PR1000        / then move axis #1
```

WD — set analog voltage at D/A channel

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **WDnn,mm**

PARAMETERS

Description
nn [int] — D/A channel number
mm [int] — analog voltage value

Range
nn — **1** to **4**
mm — **0** or **255**

Units
nn — none
mm — none

Defaults
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER
mm missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command is used to create a desired analog output voltage at any of the four MM3000 digital to analog converter outputs. See Section 7 for more information on the use of the digital to analog converters.

The output analog voltage is function of the parameter**mm** and reference voltage.

RETURNS none

ERRORS
E02 — ILLEGAL PARAMETER
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE
```
WD2,255          / set voltage to full scale at D/A channel #2
```

program execution flow control — WHILE .. WEND

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **WHILE n_1x_1, n_2x_2, ... , n_8x_8**
.
.
WEND

PARAMETERS

Description	**n**	—	input bit
	x	—	logic level
Range	**n**	—	**1** to **8**
	x	—	**L** to **H**
Units	none		
Defaults	**n**	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER
	x	missing:	E02 - ILLEGAL PARAMETER
		out of range:	E02 - ILLEGAL PARAMETER

DESCRIPTION If the condition specified with **nx** is true, commands are executed until the WEND statement is encountered. Then, the MM3000 returns to the WHILE statement and checks the bit condition. If the condition is still true, the process is repeated. If it is not true, execution resumes with the command following the WEND statement. WHILE/WEND loops may not be nested. An unmatched WHILE statement generates a WHILE WITHOUT WEND error, and an unmatched WEND statement generates a WEND WITHOUT WHILE error during compilation.

Note that bits used in this command have to be defined as inputs with BI command.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER
E30 — NESTED WHILE/WEND NOT ALLOWED
E31 — WEND WITHOUT WHILE FOUND
E32 — WHILE WITHOUT WEND FOUND

REL. COMMANDS
BI — define input bits
IF/THEN — flow control construct
WB — wait bit high/low

EXAMPLE

```
EP                  / enter program mode
BI2,7               / define input bits 2 & 7
WHILE 2H,7L         / loop while bit #2 is high  and bit #7 is low
3PR1000;WS          / initiate move and wait for stop
WEND                / end while loop
%
```

WP — wait for position

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxWPnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — position to wait

Range

xx — **1** to **4**
nn — **0** to ±**1,000,000,000** **(DC Motor)**
nn — **0** to ±**2,147,483,648** **(Stepping Motor)**

Units

xx — none
nn — encoder counts or steps

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION

This command causes the MM3000 to wait until the desired absolute position **nn** is reached before processing the next command. This command is useful for axis synchronization.

For stepping motors, the units of the parameter **nn** are either encoder counts or motor steps. The choice is made with the FM command.

For DC motors, the units of the parameter are always encoder counts.

Note:
While the MM3000 is executing this command, all front panel displays show the message: "WORKING".

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

WS — wait for stop
WT — wait time

EXAMPLE

```
1DH,2DH        / define home for axis 1 and 2
1PA-1000       / move axis # 1 to position –1000
1WP-500        / wait for axis #1 to cross position –500
2PA100         / then move axis #2 to position 100
```

wait for motion to stop — WS

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxWSnn**

PARAMETERS

Description	**xx** [int]	—	axis number
	nn [int]	—	delay after motion is complete
Range	**xx**	—	**1** to **4**
	nn	—	**0** to **32767**
Units	**xx**	—	none
	nn	—	milliseconds
Defaults	**xx** missing:		last axis specified with the previous command
	out of range:		E01 - BAD COMMAND
	nn missing:		defaults to 0
	out of range:		E02 - ILLEGAL PARAMETER

DESCRIPTION This command stops command execution until a move is completed on the specified axis before proceeding to execute the next command. A time parameter **nn** may be used for the MM3000 to add a delay after the move is complete.

The MM3000 will normally execute commands as they are received or read out of its program buffer without waiting for previous commands to be completed. Thus it is necessary to explicitly tell the MM3000 to wait for the completion of the previous command before processing the next command if that is the result that you desire.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
WT — wait time
WP — wait for position
WA — wait for all axes to stop

EXAMPLE

```
2PA1000      / move axis # 2 to position 1000
2WS500       / wait until position is reached plus an additional 0.5 seconds
3PA5000      / then move axis # 3 to position 5000
```

WT — wait time interval

USAGE ■ IMM ■ PGM ■ MIP

SYNTAX **xxWTnn**

PARAMETERS

Description

xx [int] — axis number
nn [int] — wait time (delay)

Range

xx — **1** to **4**
nn — **0** to **32767**

Units

xx — none
nn — milliseconds

Defaults

xx missing: last axis specified with the previous command
out of range: E01 - BAD COMMAND
nn missing: E02 - ILLEGAL PARAMETER
out of range: E02 - ILLEGAL PARAMETER

DESCRIPTION This command directs the MM3000 to wait the specified time, and then execute the next command.

RETURNS none

ERRORS

E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS

WP — wait for position
WS — wait for stop
WA — wait for all axes to stop

EXAMPLE

```
2PA1000      / initiate  axis #2 motion towards position 1000
WT4000       / wait 4 seconds
3PA-1000     / then initiate axis #2 motion
```

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **XX**

PARAMETERS none

DESCRIPTION This instruction is used to purge the contents of the non-volatile memory. All previously stored program instructions, trajectory parameters, and options are erased and replaced with default values.

CAUTION

Use this instruction only if the MM3000 non-volatile memory becomes corrupted and causes faulty operation.

Note:
It is necessary to reconfigure all axes with the necessary parameters (e.g., TY, OH, etc.) after this command is used.

This command affects the following parameters:

AC	JA	PE
AD	JH	SD
BA	JW	SL
CL	KD	TR
CO	KI	TY
DC	KP	UA
DS	OA	US
FE	OH	UU
FM	OL	UV
FO	OM	VA
FS	OR	VB
IL	OV	

RETURNS none

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE **XX** / *purge program and variable storage memory*

% — exit program entry mode

USAGE ■ IMM ☐ PGM ☐ MIP

SYNTAX **%**

PARAMETERS none

DESCRIPTION The percent character causes the MM3000 to exit program entry mode and re-enter command mode.

RETURNS none

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS **EP —** enter program entry mode

EXAMPLE

```
EP          / enter program mode
2PA1000     / position axis #2
2WS         / wait for stop
1PA-1000    / position axis #1
%           / exit program mode and re-enter command mode
CP          / compile program
```

USAGE ☐ IMM ■ PGM ☐ MIP

SYNTAX ‘

PARAMETERS none

DESCRIPTION Characters received after an apostrophe are not evaluated during compilation and are used as program line comments.

This command can only be used in stored programs.

RETURNS none

ERRORS E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS none

EXAMPLE

```
EP                    / enter program mode
1PA1000 ‘ FIRST TARGET     / position command with comment
2PA1000 ‘ SECOND TARGET    / position command with comment
%                     / exit program mode
```

— emergency stop

USAGE ■ IMM □ PGM ■ MIP

SYNTAX #

PARAMETERS none

DESCRIPTION The pound sign character (#) command is provided for an emergency situation where all moves must be aborted and previously transmitted commands not yet executed in the buffer should be ignored.

This command is not queued in the MM3000 command buffer. It has the highest priority. It is executed immediately regardless of the MM3000 command execution state.

This command must be used if it is necessary to stop motion immediately while the MM3000 is executing a wait command, for example,WS, WT, WP or WA or any other wait command.

Note:
Do not terminate this command with a carriage return terminator.

RETURNS none

ERRORS
E01 — BAD COMMAND
E02 — ILLEGAL PARAMETER

REL. COMMANDS
AB — abort motion with infinite deceleration
ST — abort motion with programmed deceleration

EXAMPLE
```
#                    / stop all motion immediately and abruptly
```

Section 4
Motion Control Tutorial

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Section 4 — Motion Control Tutorial

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Section 4
Motion Control Tutorial

4.1 Motion Systems

A schematic of a typical motion control system is shown in **Fig. 4.1**.

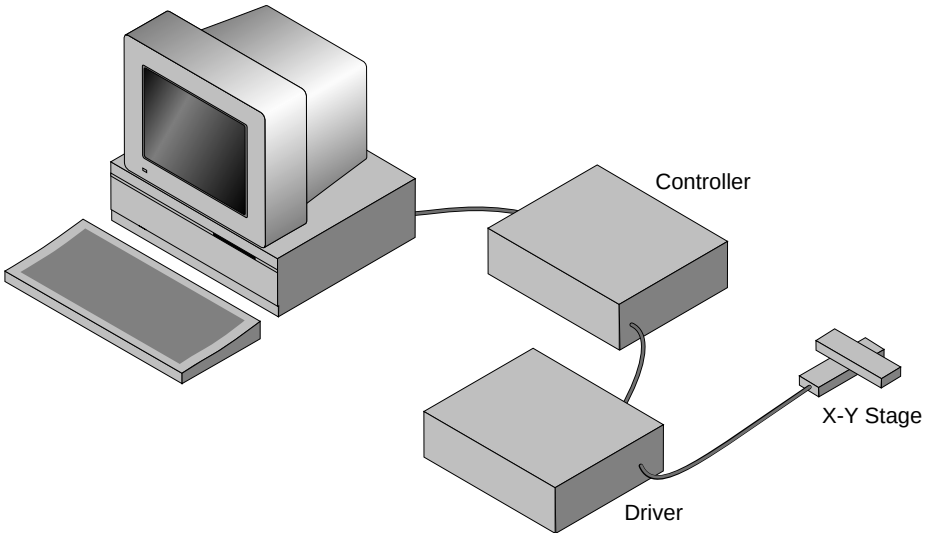

Fig. 4.1—Typical Motion Control System

Its major components are:

Controller an electronic device that receives motion commands from an operator directly or via a computer, verifies the real motion device position and generates the necessary control signals.

Driver an electronic device that converts the control signals to the correct format and power needed to drive the motors.

Motion device an electro-mechanical device that can move a load with the necessary specifications.

Cables needed to interconnect the other motion control components.

Most motion control users start by selecting a motion device that matches certain specifications needed for an application. Next, a controller that can satisfy the required motion characteristics required is chosen. But one thing has to be sure; the components put together perform reliably according to the specifications.

A component is only as good as the system lets (or helps) it be. For that reason, when discussing a particular system performance specification, it has to be mentioned which components affect performance the most and, if appropriate, which components improve it.

4.2 Specification Definitions

To establish some common ground for motion control terminology, here are some general guidelines for the interpretation of motion control terms and specifications.

- As mentioned earlier, most motion control performance specifications should be considered system specifications.
- If not otherwise specified, all error-related specifications refer to the position error.
- The servo loop feedback is position-based. All other parameters (velocity, acceleration, error, etc.) are derived from the position feedback and the internal clock.
- To measure absolute position, a measuring device is needed that is significantly more accurate than the device under test. When dealing with fractions of microns (0.1mm and less), even a standard laser interferometer becomes unsatisfactory. For that reason, all factory measurements are made using a number of high precision interferometers, most of them connected to a computerized test station.
- To avoid unnecessary confusion and to more easily understand and troubleshoot a problem, special attention must be paid not to group *discrete* errors in one general term. Depending on the application, some discrete errors are not significant. Grouping them in one general parameter will only complicate the understanding of the system performance in certain applications.

4.2.1 Following Error

The **Following Error** is not a *specification* parameter but it deserves special attention.

As will be described later in the **Control Loops** paragraph, a major part of the servo controller's task is to make sure that the *actual* motion follows an *ideal* trajectory as closely as possible. In reality, real motion will deviate from an ideal trajectory. Since most of the time *real* motion is trailing the *ideal* trajectory, the instantaneous error is called **Following Error**.

To summarize: **Following Error** is the instantaneous difference between the actual position as reported by the position feedback device and the ideal position, as commanded by the motion controller. A negative following error means that the load is leading the ideal motion device.

4.2.2 Error

Error has the same definition as the *Following Error* with the exception that the ideal trajectory is not compared to the position feedback device (encoder) but to an external precision measuring device.

In other words, the *Following Error* is the instantaneous error perceived by the controller while the **Error** is the one perceived by the user.

4.2.3 Accuracy

The **Accuracy** of a system is probably the most common parameter users want to know. Unfortunately, due to its perceived simplicity, it is also easy to misinterpret.

Accuracy is a static measure of a point-to-point positioning error. Starting from a reference point, command the controller to move a certain distance. When the motion is completed, measure the actual distance traveled with an external precision position measuring device. The difference (the *Error*) represents the positioning **Accuracy** for that particular motion.

Because every application is different, one needs to know the errors for all possible motions. Since this is practically impossible, an acceptable compromise is to perform the following test.

Starting from one end of travel, small incremental moves are performed and at every stop the position *Error* recorded. This operation must be repeated over the entire nominal travel range. When finished, the Error data is plotted on a graph similar to **Fig. 4.2**.

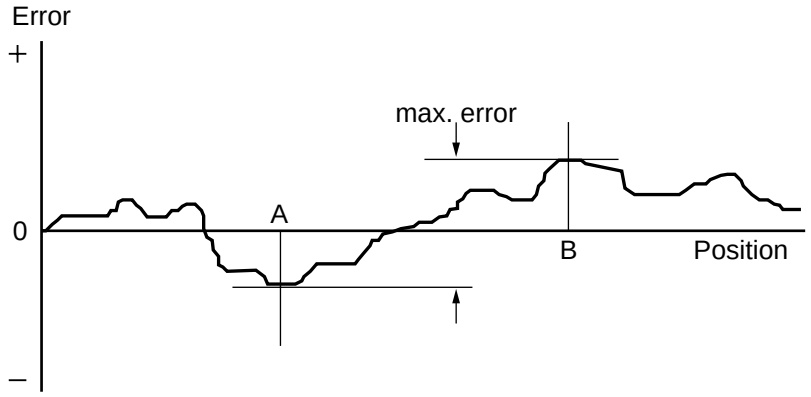

Fig. 4.2— Position Error Test

The difference between the highest and the lowest points on the graph is the maximum possible *Error* that the motion device can have. This worst-case number is reported as the positioning **Accuracy**. It guaranties the user that for any application, the positioning error will not be greater than this value.

4.2.4 Local Accuracy

For some applications, it is important to know not just the positioning *Accuracy* over the entire travel but also over a small distance. To illustrate this case, **Fig. 4.3-a** and **Fig. 4.3-b** show two extreme cases.

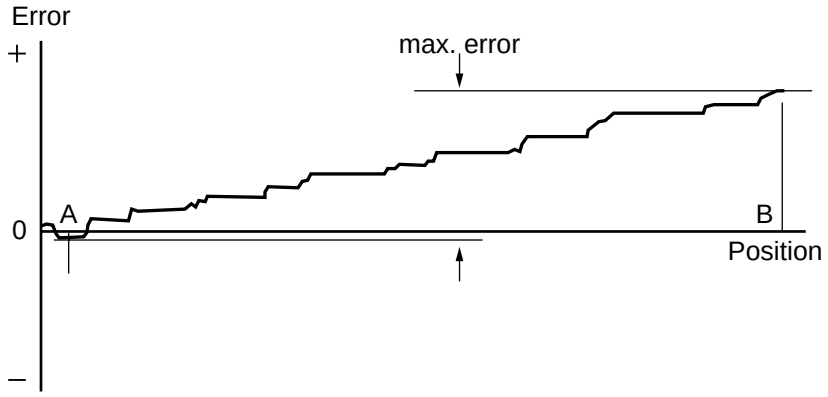

Fig. 4.3-a— High Local Accuracy for Small Motions

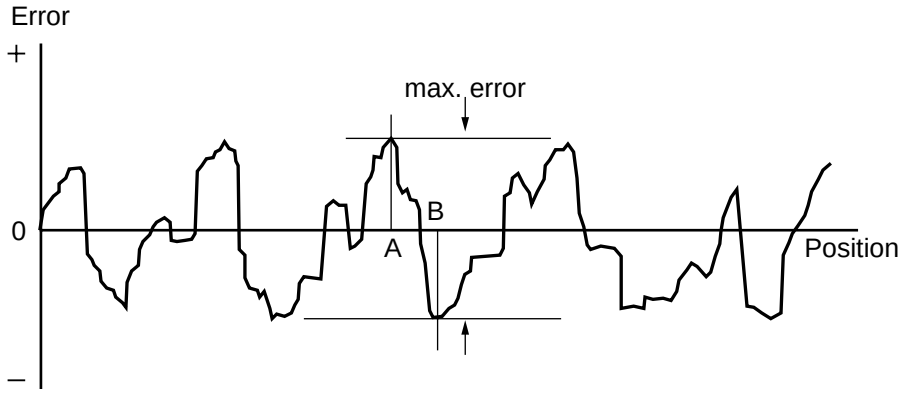

Fig. 4.3-b—Low Local Accuracy for Small Motions

Both error plots from **Fig. 4.3-a** and **Fig. 4.3-b** have a similar maximum *Error*. But, if the maximum *Error* for small distances is compared, the system in **Fig. 4.3-b** shows significantly larger values. For application requiring high accuracy for small motions, the system in **Fig. 4.3-a** is definitely preferred.

"Local Error" is a relative term that depends on the application; usually no **Local Error** value is given with the system specifications. The user should study the error plot supplied with the motion device and determine the approximate maximum **Local Error**.

4.2.5 Resolution

Resolution is the smallest motion that the controller is able to make. For most of DC motor and most standard stepper motor driven stages supported by the MM3000, this is also the resolution of the encoder.

Keeping in mind that the servo loop is a digital loop, the **Resolution** can also be viewed as the smallest position increment that the controller can perform.

4.2.6 Minimum Incremental Motion

The **Minimum Incremental Motion** is the smallest motion that a device can reliably make, measured with an external position measuring device. The controller can, for instance, command a motion equal to the *Resolution* (one encoder count) but in reality the load may not move at all. The cause for this is in the mechanics.

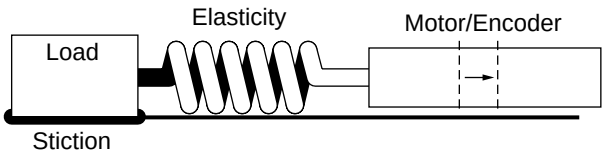

Fig. 4.4—Effect of Static Friction and Elasticity on Small Motions

Fig. 4.4 shows how excessive stiction (static friction) and elasticity between the encoder and the load can cause the motion device to deviate from ideal motion when executing small motions.

The effect of these two factors has a random nature. Sometimes, for a small motion step of the motor, the load may not move at all. Other times, the accumulated energy in the *spring* will cause the load to *jump* a larger distance. The error plot will be similar to **Fig. 4.5**.

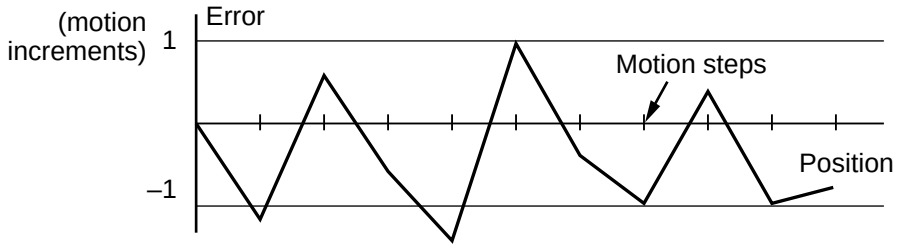

Fig. 4.5—Error Below Minimal Incremental Motion

Once the **Minimum Incremental Motion** is defined, the next task is to quantify it. This is more difficult for two reasons: one is its random nature and the other is in defining what a *completed motion* represents.

Assume that a motion device has 1μm resolution. If every time a commanded move of 1mm results in an error less than 2%, it would propably satisfy the requirements and one could declare that the **Minimum Incremental Motion** is 1μm. If, on the other hand, the measured motion is sometimes as small as 0.1μm (a 90% error), it could not be said that a 1mm move was reliably executed. It is difficult to draw the line between acceptable and unacceptable errors when performing a small motion step. The most common value for the maximum acceptable error for small motions is 20%, but each application ultimately has its own standards.

One way to solve the problem is to take a large number of measurements (a few hundred at minimum) and present them in a format that an operator can use to determine the **Minimum Incremental Motion** by its own standards.

Fig. 4.6 shows an example of such a plot. The graph represents the maximum relative error for different motion step sizes. In this example, the**Minimum Incremental Motion** that can be reliably performed with a maximum of 20% error is one equivalent to 4 *resolution* (encoder) increments.

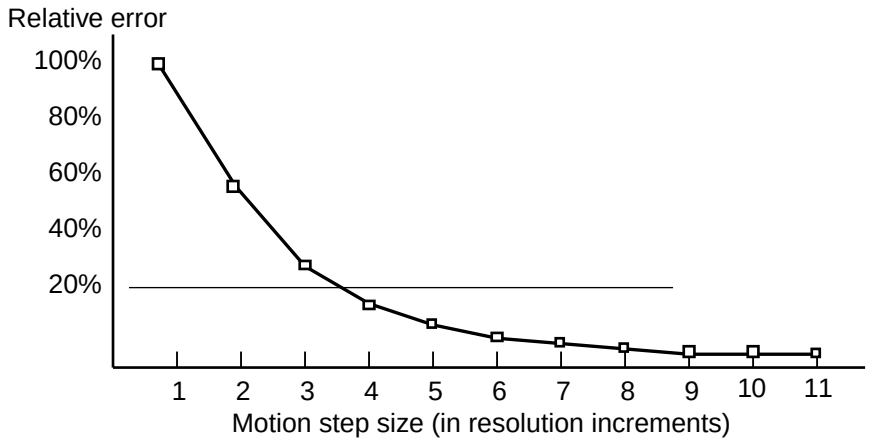

Fig. 4.6—Error vs Motion Step Size

4.2.7 Repeatability

Repeatability is the positioning variation when executing the same motion profile. Assuming that a motion sequence stops at a number of different locations; then the **Repeatability** is the maximum position variation at all targets when the same motion sequence is repeated a large number of times. It is a relative, not absolute, error between identical motions.

4.2.8 Backlash (Hysteresis)

For all practical purposes, **Hysteresis** and **Backlash** have the same meaning for motion control systems. The term **Hysteresis** has an electro-magnetic origin while **Backlash** comes from mechanical engineering. Both describe the same phenomenon: the error caused when approaching a point from a different direction.

All parameters discussed up to now that involve the positioning*Error* assumed that all motions were performed in the same direction. If the positioning error of a certain target (destination) is measured, approaching the destination from different directions could make a significant difference.

The plot in **Fig. 4.2** was generated by making a large number of incremental moves, from one end of travel to the other. If the motion device is then commaned to move back and stop at the same locations to take a position error measurement, one could expect to get an identical plot, superimposed on the first one. In reality, the result is more like shown in**Fig. 4.7**.

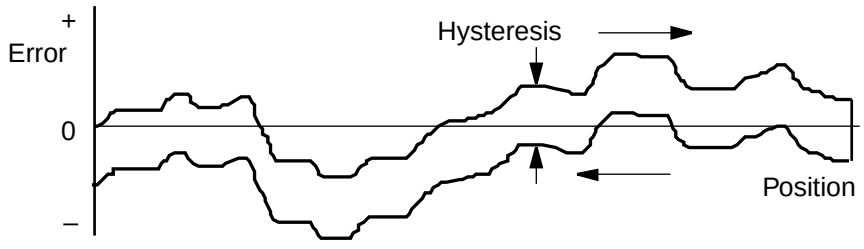

Fig. 4.7—Hysteresis Plot

The error plot in reverse direction is identical with the first one but seems to be shifted down by a constant error. This constant error is the **Hysteresis** of the system.

To justify a little more why this error is called **Hysteresis**, lets do the same graph in a different format (**Fig. 4.8**), plotting the real versus the ideal position.

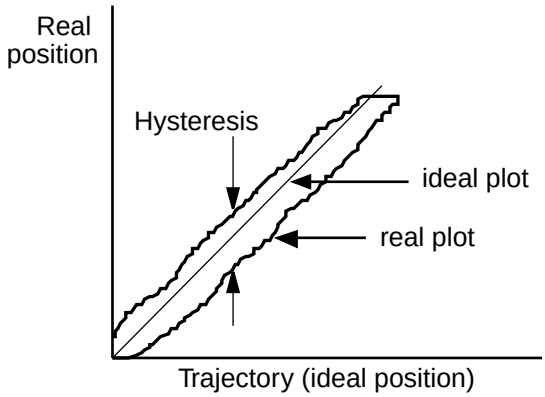

Fig. 4.8—Real vs Ideal Position

4.2.9 Pitch, Roll and Yaw

These are the most common *angular* error parameters for **linear translation stages**. They are entirely mechanical errors and represent the rotational error of a stage carriage around the three axes. A perfect stage should not rotate around any of the axes, thus the **Pitch**, **Roll** and **Yaw** should be zero.

The commonly used representation of the three errors is shown in **Fig. 4.9**. **Pitch** is rotation around the Y axis, **Roll** is rotation around the X axis and **Yaw** around the Z axis.

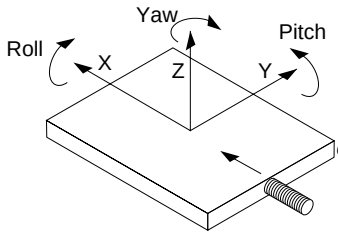

Fig. 4.9—Pitch, Yaw and Roll Motion Axes

The above definition might be difficult to remember. A more graphical representation in presented in **Fig. 4.10**. Imagine a tiny carriage driven by a giant leadscrew. When the carriage *rolls* sideways on the lead screw, it is called **Roll**. When it rides up and down on the lead screw *pitch*, it is called **Pitch**. And, when the carriage deviates left or right from the straight direction (on an imaginary *Y* trajectory), call it **Yaw**.

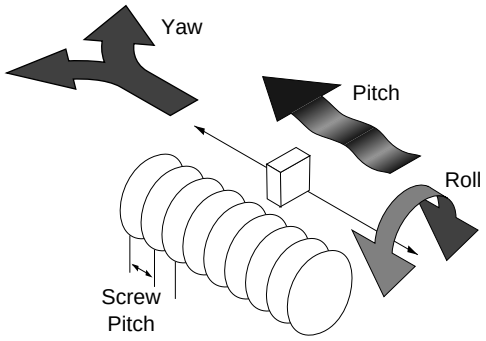

Fig. 4.10—Pitch, Yaw and Roll Motion Axes

4.2.10 Wobble

This parameter applies only to **rotary stages**. It represents the deviation of the axis of rotation during motion. A simple form of **Wobble** is a constant one, where the rotating axis generates a circle (**Fig. 4.11**).

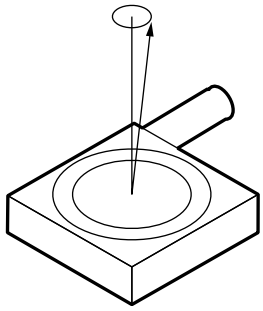

Fig. 4.11—Wobble

A real rotary stage may have a more complex **Wobble**, where the axis of rotation follows a complicated trajectory. This type of error is caused by the imperfections of the stage machining and/or ball bearings.

4.2.11 Load Capacity

There are two types of loads that are of interest for motion control applications: *static* and *dynamic loads*.

The *static* **Load Capacity** represents the amount of load that can be placed on a stage without damaging or excessively deforming it. Determining the **Load Capacity** of a stage for a particular application is more complicated than it may appear. The stage orientation and the distance from the load to the carriage play a significant role. For a detailed description on how to calculate the static **Load Capacity**, please consult the Newport motion control catalog tutorial section.

The *dynamic* **Load Capacity** refers to the motor effort to move the load. The first criterion is how much load the stage can *push* or *pull*. In some cases the two values (push and pull) could be different due to internal mechanical construction.

The second type of *dynamic* **Load Capacity** refers to the maximum load that the stage could move with the nominal acceleration. This parameter is more difficult to determine because it involves defining an acceptable *following error* during acceleration.

4.2.12 Maximum Velocity

The **Maximum Velocity** that could be used in a motion control system is determined by both motion device and driver. Usually it represents a lower value than the motor or driver are capable of. The hardware and firmware are tuned for a particular maximum velocity that cannot be exceeded.

4.2.13 Minimum Velocity

The **Minimum Velocity** usable with a motion device depends on the motion control system but also on the acceptable *velocity regulation*. The encoder resolution determines the motion increment size and the application sets a limit on the velocity.

To illustrate this, take the example of a linear stage with a resolution of 0.1μm. If the velocity is set to 0.5μm/s, the stage should move 5 encoder counts in one second. Yet, a properly tuned servo loop could move the stage 0.1μm in minimum time of about 20ms. The position and velocity plots are illustrated in **Fig. 4.12**.

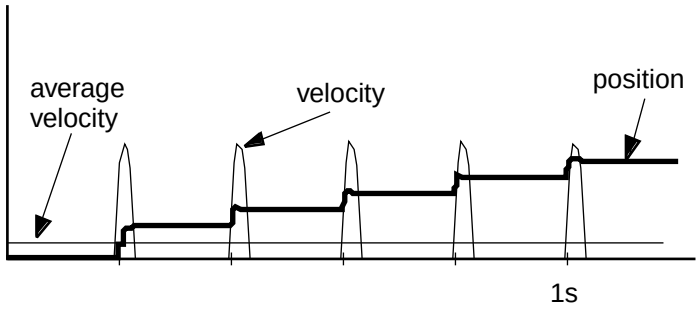

Fig. 4.12—Position, Velocity and Average Velocity

The average velocity is low but the *velocity ripple* is very high. Depending on the application, this may be acceptable or not. With increasing velocity, the *ripple* decreases and the velocity becomes smoother.

This example is even more true in the case of a stepper motor driven stage. The typical *noise* comes from a very fast transition from one step position to another. The velocity ripple in that case is significantly higher.

In the case of a DC motor, adjusting the PID parameters to get a *softer* response will reduce the velocity ripple but care must be taken not to adversely affect other desirable motion characteristics.

4.2.14 Velocity Regulation

In some applications, for example scanning, it is important for the velocity to be very constant. There are a number of factors besides the controller that affect the velocity.

As described in the *Minimum Velocity* definition, the speed plays a significant role in the amount of ripple generated, specially at low values.

Even if the controller does a perfect job by running with zero following error, imperfections in the mechanics (friction variation, transmission ripple, etc.) will generate some velocity ripple that can be thought of as a **Velocity Regulation** problem.

Depending on the specific application, one motor technology can be preferred over the other.

As far as the controller is concerned, the stepper motor version is the ideal case for a good *average* **Velocity Regulation** because the motor inherently follows precisely the desired trajectory. The only problem is the *ripple* caused by the actual stepping process.

The best a DC motor controller can do is to approach the stepper motor's performance in *average* **Velocity Regulation**, but it has the advantage of significantly reduced velocity ripple.

4.2.15 Maximum Acceleration

The **Maximum Acceleration** is a complex parameter that depends as much on the motion control system as it does on application requirements. For stepper motors, the main concern is not to lose steps (or synchronization) during acceleration. Besides the motor and driver performance, the load inertia plays a significant role.

For DC motor systems the situation is different. If the size of the *following error* is of no concern during acceleration, high **Maximum Acceleration** values can be entered. The motion device will move with the highest natural acceleration it can (determined by the motor, driver, load inertia, etc.) and the errors will be just a temporary larger following error and a velocity overshoot.

In any case, special consideration should be given when setting acceleration. Though in most cases no harm will be done by setting a high acceleration value, avoid doing so if the application does not require it. The driver, motor, motion device **and** load undergo maximum stress during high acceleration.

4.2.16 Combined Parameters

Very often a user looks at an application and concludes that he needs a certain *overall accuracy*. This usually means that he is combining a number of individual terms (error parameters) into a single one. Some of these combined parameters even have their own name, even though not everybody means the same thing by them: *Absolute Accuracy*, *Bi-directional Repeatability*, etc. The problem with these generalizations is that, unless the term is well defined and the testing closely simulates the application, the numbers could be of little value.

The best approach is to carefully study the application, extract from the specification sheet the applicable discrete error parameters and combine them (usually add them) to get the worst-case general error applicable to the specific case. This method not only offers a more accurate value but also gives a better understanding of the motion control system performance and helps pinpoint problems.

Also, due to the integrated nature of the MM3000 system, many basic errors can be significantly corrected; i.e., *Backlash Compensation* and *Linear Compensation* (see Command Section).

4.3 Control Loops

When talking about motion control systems, one of the most important questions is the type of servo loop implemented. The first major distinction is between open and closed loops. Of course, this is of particular interest when driving stepper motors. As far as the DC servo loops, the PID type is by far the most widely used.

The MM3000 implements a PID servo loop for DC motors. It is not just a static closed loop, when the motion is stopped, but a fully dynamic one. That means the servo loop is updated every servo cycle (256 μsec).

The basic diagram of a servo loop is shown in **Fig. 4.13**. Besides the command interpreter, the main two parts of a motion controller are the trajectory generator and the servo controller. The first generates the desired trajectory and the second one controls the motor to follow it as closely as possible.

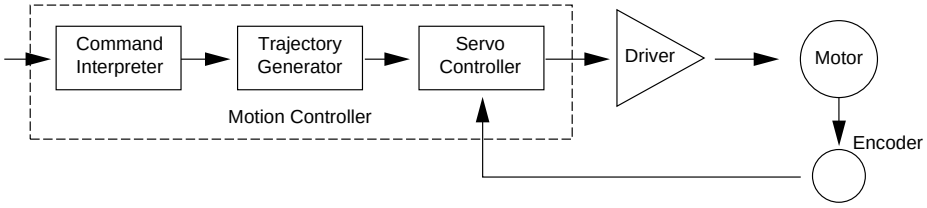

Fig. 4.13—Servo Loop

4.3.1 PID Servo Loops

PID is an acronym for *proportional*, *integral* and *derivative* gain factors that are the basis of the control loop calculation. The common equation given for it is:

$$K_p \bullet e + K_i \int e\,dt + K_d \bullet \frac{de}{dt}$$

where K_p = proportional gain factor

K_i = integral gain factor

K_d = derivative gain factor

e = instantaneous following error

It is difficult to get a feeling for this formula, especially when trying to *tune* the PID loop. *Tuning* the PID means changing its three gain factors to obtain a certain system response, a task quite difficult to achieve without some understanding of the basic behavior of servo loops.

The following paragraphs explain the PID components and their operation.

P Loop

Lets start with the simplest type of closed loop, the **P** (proportional) loop. **Fig. 4.14** shows its configuration.

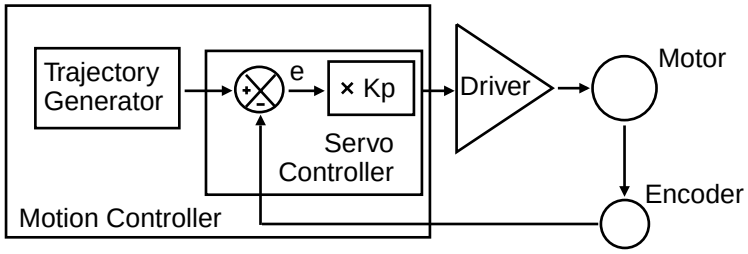

Fig. 4.14— P Loop

Each servo cycle, the actual position, as fed back by the encoder, is compared to the desired position generated by the trajectory generator. The difference **e** is the positioning error (the *following error*). Amplifying it (multiplying it by $\mathbf{K_p}$) generates a *control signal* that, converted to an analog signal, is sent to the motor driver.

There are a few conclusions that can be drawn from this circuit:

— The motor control signal, thus the motor voltage, is proportional to the following error.

— There must be a following error in order to drive the motor.

— Higher velocities need higher motor voltages and thus higher following errors.

— At stop, small errors cannot be corrected if they don't generate enough voltage for the motor to overcome friction and stiction.

— Increasing the $\mathbf{K_p}$ gain reduces the necessary following error but if it is too high it will generate instabilities and oscillations.

PI Loop

To eliminate the error at stop and during long constant velocity motions (usually called *steady-state* error), an *integral* term can be added to the loop. This term integrates the error every servo cycle and the value, multiplied by the $\mathbf{K_i}$ gain factor, is added to the control signal (**Fig. 4.15**).

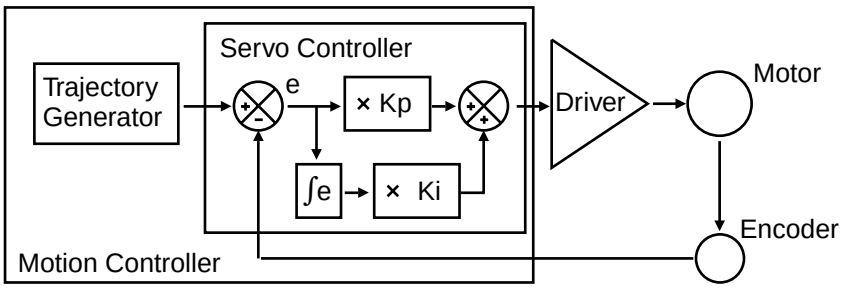

Fig. 4.15—PI Loop

If $\mathbf{K_p}$ is set to 0, the integral term increases until it drives the motor by itself, reducing the following error to zero. At stop, this has the desirable effect of driving the positioning error to zero. During a long constant-velocity motion it also brings the following error to zero, an important feature for some applications.

Unfortunately, the integral term also has a negative side: a de-stabilizing effect on the servo loop. In the real world, a simple **PI** loop is almost never used.

PID Loop

The third term of the **PID** loop is the *derivative* term. It is defined as the difference between the following error of the current servo cycle and of the previous one. If the following error does not change, the *derivative* term is zero.

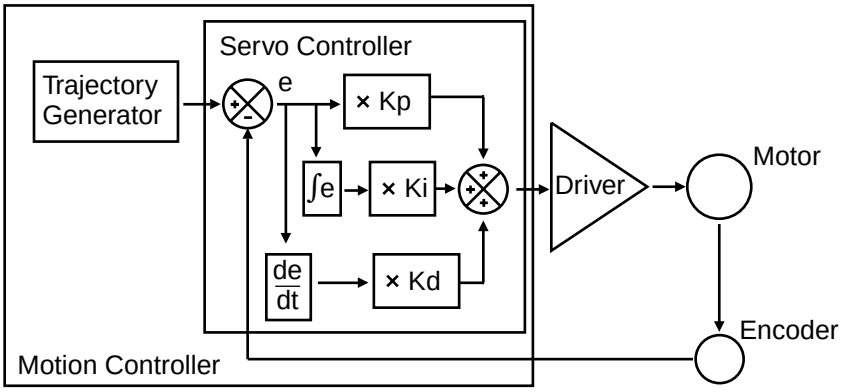

Fig. 4.16—PID Loop

Fig. 4.16 shows the PID servo loop diagram. The *derivative* term is added to the *proportional* and *integral* one. All three process the following error in their own way and, added together, form the control signal.

The *derivative* term adds a damping effect which prevents oscillations and position overshoot.

4.4 Motion Profiles

In the contex of this manual, the term *motion command* refers to certain string sent to a motion controller that will initiate a certain action, usually a motion. There are a number of common motion commands which are identified by name. The following paragraphs describe a few of them.

4.4.1 Move

A *move* is a point-to-point motion. On execution of a *move* command, the motion device moves from the current position to a desired destination. The destination can be specified either as an absolute position or as a relative distance from the current position.

When executing a move command, the motion device will accelerate until the velocity reaches a pre-defined value. Then, at the proper time, it will start decelerating so that when the motor stops, the device is at the correct position. The velocity plot of this type of motion will have a trapezoidal shape (**Fig. 4.17**). For this reason, this type of motion is called a *trapezoidal motion*.

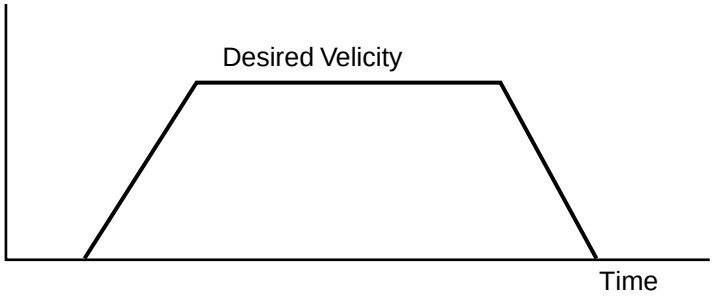

Fig. 4.17—Trapezoidal Motion Profile

The position and acceleration profiles relative to the velocity are shown in **Fig. 4.18**.

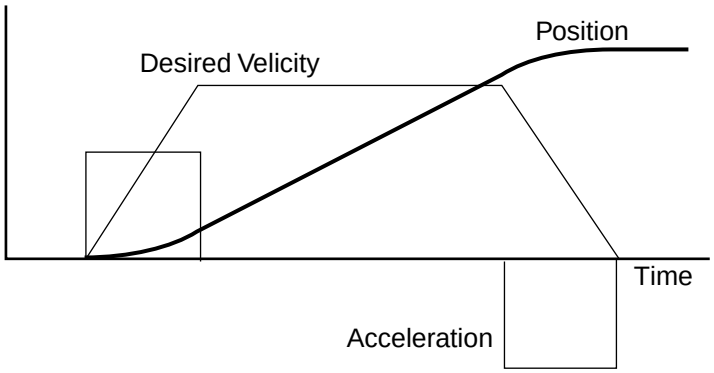

Fig. 4.18—Position and Acceleration Profiles

Along with the destination, the acceleration and the velocity of the motion (the constant portion of it) can be set by the user before every *move* command. Advanced controllers like the MM3000 allow the user to change them even during motion. However, the MM3000 always verifies that a parameter change can be safely performed.

4.4.2 Jog

When setting up an application, it is often necessary to move a devices manually while observing motion. The easy way to do this without resorting to specialized input devices such as joysticks or track-wheels is to use simple push-button switches. This type of motion is called a*jog*. When a jog button is pressed the selected axis starts moving with a pre-defined velocity. The motion continues only while the button is pressed and stops immediately after its release.

The MM3000 offers two *jog* speeds. Both high speed and low speed are programmable. The acceleration used for jogging can also be programmed.

4.4.3 Home Search

Home search is a specific motion routine that is useful for most types of applications. Its goal is to very accurately and repeatably find a specific point in travel relative to the mounting base of the motion device. The need for this *absolute* reference point is twofold. First, in many applications it is important to know the exact position in space, even after a power-off cycle. Secondly, to protect the motion device from hitting a travel obstruction set by the application (or its own travel limits), the controller uses programmable software limits. To be efficient though, the software limits must be placed accurately in space before running the application.

To achieve this precise position referencing, the MM3000 motion control system executes a unique sequence of moves.

First, lets look at the hardware required to determine the position of a motion device. The most common (and the one supported by the MM3000) are incremental encoders. By definition, these are encoders that can measure only relative moves, not absolute position. The controller keeps track of position by incrementing or decrementing a dedicated counter according to the information received from the encoder. Since there is no absolute position information, position “zero” is where the controller was powered on (and the position counter reset).

To determine an absolute position, the controller must find a “switch” that is unique to the entire travel range, called a*home switch* or *origin switch*. An important requirement is that this switch must be located with the same accuracy as the encoder pulses. If the motion device is using a linear scale as position encoder, the home switch is usually placed on the same scale and read with the same accuracy. If, on the other hand, a rotary encoder is used, the problem becomes more complicated. To have the same accuracy, a mark on the encoder disk could be used (called*index* pulse) but because it repeats itself every revolution, it does not define a unique point over the entire travel. An *origin switch*, on the other hand, placed in the travel of the motion device is unique but not accurate (repeatable) enough. The solution is to use both.

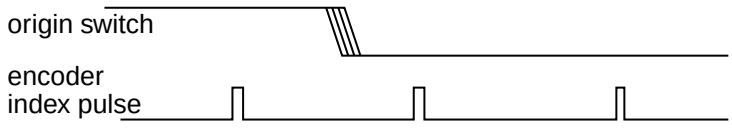

Fig. 4.19—Origin switch and encoder index pulse

An *origin switch* (**Fig. 4.19**) separates the entire travel into two areas: one for which it has a high level and one for which it is low. The most important part of it is the transition between the two areas. Also, looking at the origin switch level, the controller knows on which side the stage currently is located and which way to move to find the origin.

The task of the *home search* routine is to identify one unique index pulse as the absolute position reference. This is done by first finding the origin switch transition and then the first index pulse (**Fig. 4.20**).

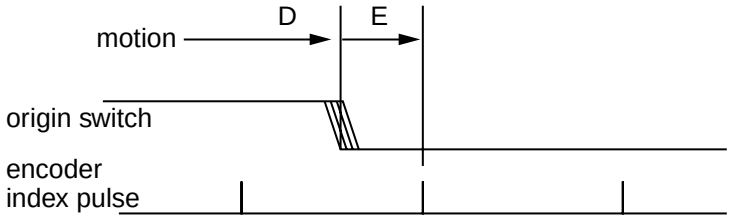

Fig. 4.20—Slow-Speed Origin Switch Search

Let's label the two motion segments D and E. During D, the controller is looking for the origin switch transition and during E for the index pulse. To guarantee the best accuracy possible, both D and E segments are performed at a very low speed and without a stop in-between. Also, during E the display update is suppressed to eliminate any unnecessary overhead.

The routine described above works but has one disadvantage. Using the low speeds, it could take a very long time if the motion device happens to start from the opposite end of travel. To speed the process up the motion device moves fast to the vicinity of the origin switch and then perform the two slow motions, D and E. The new sequence is shown in **Fig. 4.21**.

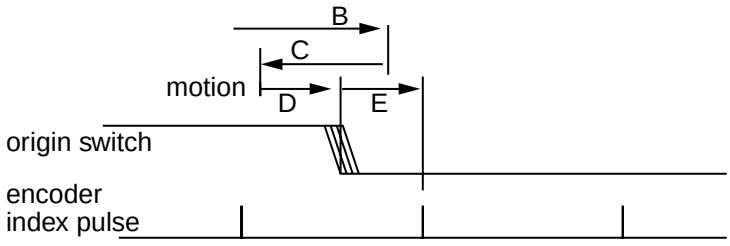

Fig. 4.21—High/Low-Speed Origin Switch Search

Motion segment B is performed at high speed, with the pre-programmed home search speed. When the origin switch transition is encountered, the motion device stops (with an overshoot), reverses direction and looks for it again, this time with half the low home velocity (segment C). Once found, it stops again with an overshoot, reverses direction and executes D and E.

Below you will find a case where the motion device starts from the other side of the origin switch transition (**Fig. 4.22**).

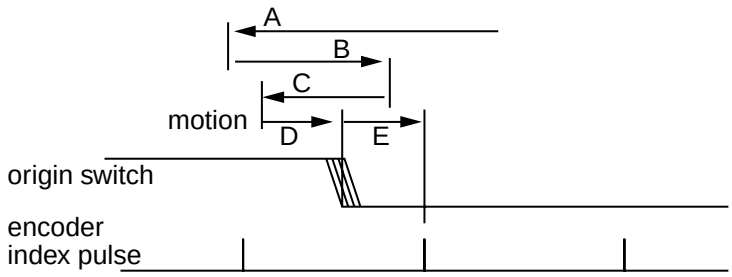

Fig. 4.22—Origin Search From Opposite Direction

The MM3000 moves at high speed up to the origin switch transition (segment A) and then executes B, C, D and E.

All *home search* routines are run so that the last segment, E, is performed in the positive direction of travel.

CAUTION

The home search routine is a very important procedure for the positioning accuracy of the entire system and it requires full attention from the controller. Do not interrupt or send other commands during its execution, unless it is for emergency purposes.

4.5 Encoders

PID closed-loop motion control requires a position sensor. The most widely used technology are incremental encoders.

The main characteristic of an incremental encoder is that it has a 2-bit gray code output, more commonly known as *quadrature* output (**Fig. 4.23**).

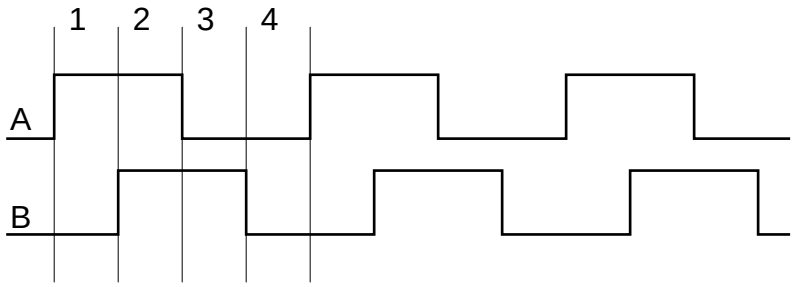

Fig. 4.23—Quadrature Output

The output has two signals, commonly known as channel A and channel B. Some encoders have analog outputs (sine - cosine signals) but the digital type is more widely used. Both channels have a 50% duty cycle and are out of phase by 90°. Using both phases and an appropriate decoder, a motion controller can identify four different areas within one encoder cycle. This type of decoding is called **×4** (or *quadrature* decoding), meaning that the

encoder resolution is multiplied by 4. For example, an encoder with 10mm phase period can offer a 2.5mm resolution when used with a×**4** type decoder.

Physically, an encoder has two parts: a *scale* and an *read head*. The *scale* is an array of precision marks that are read by the *head*. The most commonly used encoders, optical encoders, have a scale made out of a series of transparent and opaque lines placed on a glass substrate or etched in a thin metal sheet (**Fig. 4.24**).

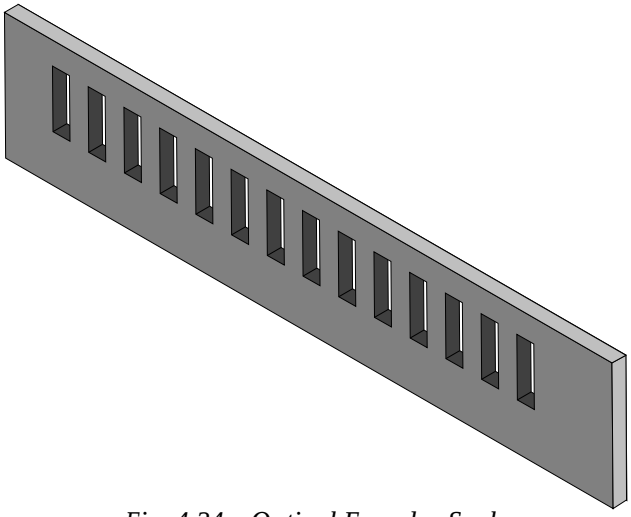

Fig. 4.24—Optical Encoder Scale

The encoder read head has three major components: a light source, a mask and a detector (**Fig. 4.25**). The mask is a small scale-like piece, having identically spaced transparent and opaque lines.

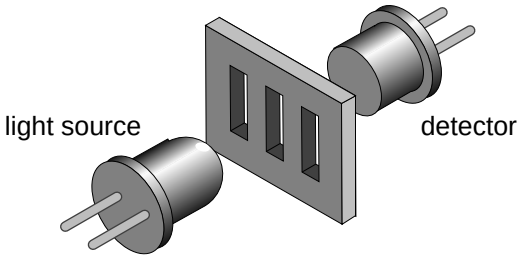

Fig. 4.25—Optical Encoder Read Head

Combining the scale with the read head, when one moves relative to another, the light will pass through where the transparent areas line up or blocked when they do not line up (**Fig. 4.26**).

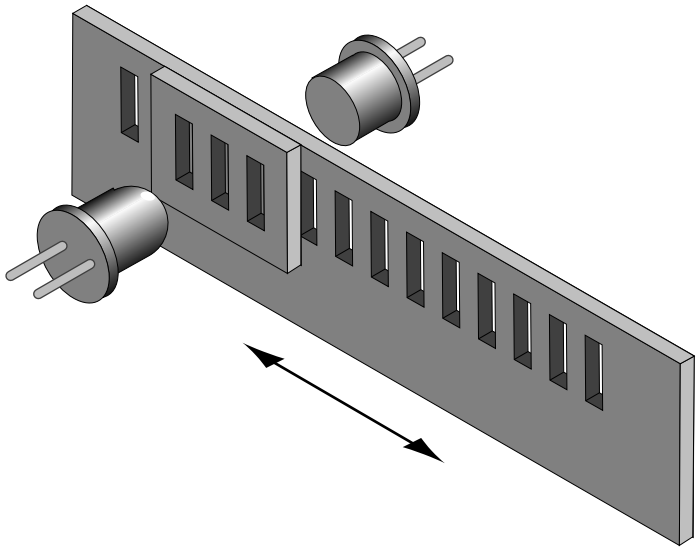

Fig. 4.26—Single-Channel Optical Encoder Scale and Read Head Assembly

The detector signal is similar to a sine wave. The desired encoder signal is obtain by converting it to a digital waveform. But, doing that results in only one phase which is only half of the signal needed to get position information. The second channel is obtained in the same fashion but from a mask that is placed 90% out of phase relative to the first one (**Fig. 4.27**).

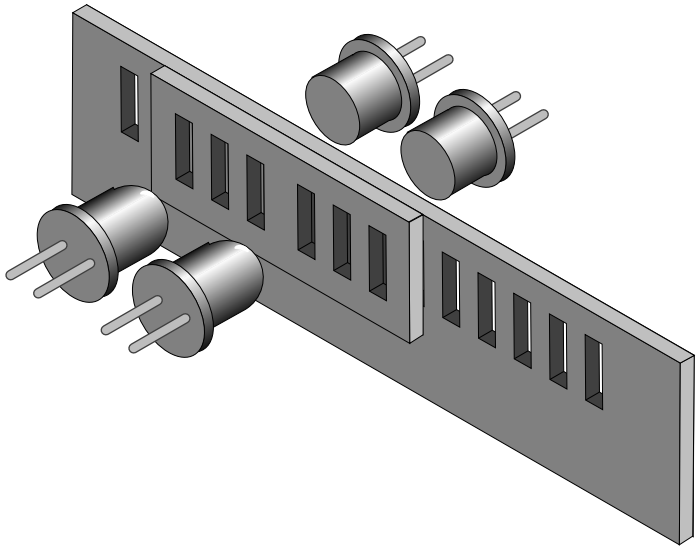

Fig. 4.27— Two-Channel Optical Encoder Scale and Read Head Assembly

There are two basic types of encoders, linear and rotary. The linear encoders, also called linear scales, are used to measure linear motion directly. This means that the physical resolution of the scale will be the actual positioning resolution. This is their main drawback since technological limitations prevent them from having better resolutions than a few microns. To get higher resolutions in linear scales, special circuitry or interferometers must be added.

The most popular encoders are rotary. Using gear reduction between the encoder and the load, significant resolution increases can be obtained at low cost. But the price paid for this added resolution is higher backlash.

In some cases, rotary encoders offer high resolution without significant backlash. For instance, a linear translation stage with a rotary encoder on the lead screw can easily achieve 1mm resolution with negligible backlash.

NOTE

For rotary stages, a rotary encoder measures the output angle directly. In this case, the encoder has the same advantages and disadvantages of the linear scales.

4.6 Motors

There are many different types of electrical motors, each one being best suitable for certain kind of applications. The MM3000 supports two of the most popular types: stepper motors and DC motors.

Another way to characterize motors is by the type of motion they provide. The most common ones are rotary but in some applications, linear motors are preferred. Though the MM3000 can drive both stepper and DC linear motors, the standard motion device family supports only rotary motors.

4.6.1 Stepper Motors

The main characteristic of a stepper motor is that each motion cycle has a number of stable positions. This means that, if current is applied to one of its windings (called phases), the rotor will try to find one of these stable points and stay there. In order to make a motion, another phase must be energized which, in turn, will find a new stable point, thus making a small incremental move—a *step*.

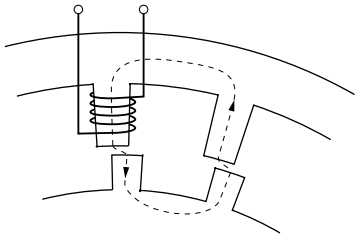

Fig. 4.28—Stepper Motor Operation

Fig. 4.28 shows the basics of a stepper motor. When the winding is energized, the magnetic flux will turn the rotor until the rotor and stator*teeth* line up. This is true if the rotor core is made out of soft iron. Regardless of the current polarity, the stator will try to pull-in the closest rotor*tooth*.

But, if the rotor is a permanent magnet, depending on the current polarity, the stator will pull or push the rotor tooth. This is a major distinction between two different stepper motor technologies: *variable reluctance* and *permanent magnet* motors. The variable reluctance motors are usually small, low cost, large step angle stepper motors. The permanent magnet technology is used for larger, high precision motors.

The stepper motor advances to a new stable position by means of several stator phases that have the teeth slightly offset from from the rotor teeth. To illustrate this, **Fig. 4.29** shows a stepper motor with four phases.

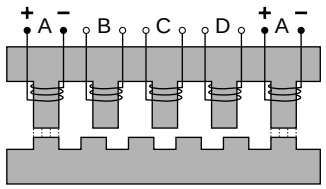

Fig. 4.29—Four-Phase Stepper Motor

The four phases, from A to D, are energized one at a time (phase A is shown twice). One of the rotor teeth lines up with the first energized phase, A. If the current to phase A is turned off and B is energized next, the closest rotor tooth to phase B will be pulled in and the motor moves one step forward.

If, on the other hand, the next energized phase is D, the closest rotor tooth is on the other side, thus making the motor to move in reverse.

Phase C cannot be energized immediately after A because it is exactly between two teeth, so the direction of movement is undetermined.

To move in one direction, the current in the four phases must have the following timing diagram:

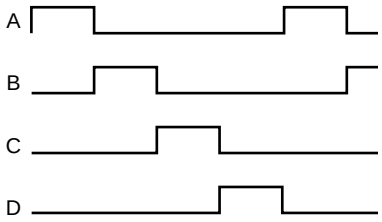

Fig. 4.30—Phase Timing Diagram

Phases are energized in sequence. To advance one full rotor tooth, a complete cycle of four steps has to be performed. A full rotor revolution is achieved when the number of steps equals four times the number of rotor teeth. These steps are called full steps. They are the largest motion increment the stepper motor can make. Running the motor in this mode is called *full-stepping.*

Lets analyze what happens if we energize two neighboring phases simultaneously (**Fig. 4.31**).

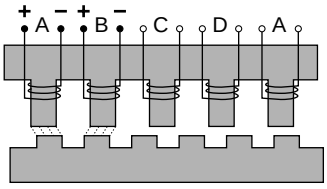

Fig. 4.31—Energizing Two Phases Simultaneously

Both phases will pull equally on the motor and move the rotor only half of the full step. If the phases are always energized two at a time, the motor still makes full steps. But, if first one phase, then two phases are being activated simultaneously, the result is that the motor will move only half a step at a time. This method of driving a stepper motor is called *half-stepping.* The result is twice the resolution from the same motor with very little effort on the driver's side. The timing diagram for half-stepping is shown in **Fig. 4.32**.

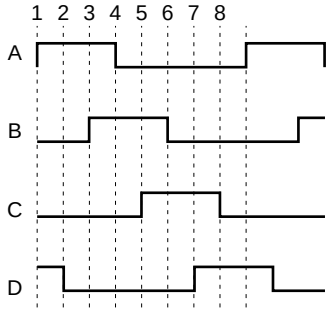

Fig. 4.32—Timing Diagram, Half-Stepping Motor

The third possibility is to energize the same two phases simultaneously but with different currents. For example, lets say that phase A has the full current and phase B only half. This means that phase A will pull the rotor tooth twice as strongly as B does. The rotor tooth will stop closer to A, somewhere between the full step and the half step positions (**Fig. 4.33**).

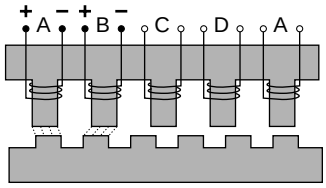

Fig. 4.33—Energizing Two Phases Simultaneously

The conclusion is that, by varying the ratio between the currents of the two phases, a position of the rotor anywhere between the two full step locations can be obtained. To do so, the motor driver has to supply analog signals similar to **Fig. 4.34**.

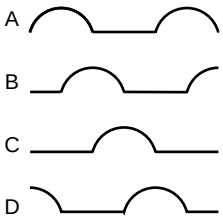

Fig. 4.34— Timing Diagram, Continuous Motion (Ideal)

But since a stepper motor should be stepping, the controller needs to move it in certain known increments. The solution is to take the half-sine waves and digitize them so that for every step command, the currents change to some new pre-defined levels, causing the motor to advance one small step (**Fig. 4.35**).

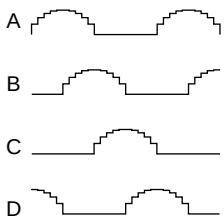

Fig. 4.35—Timing Diagram, Mini-Stepping

This driving method is called *mini-stepping* (also called micro-stepping). For each step command, the motor will move only a fraction of the full step. Motion steps are smaller so the motion resolution is increased and the motion ripple (noise) is decreased.

On most motors the MM3000 drivers use the mini-stepping technique to divide the full step in ten mini-steps, increasing the motor's resolution by a factor of 10.

However, mini-stepping comes at a price. First, the driver electronics are significantly more complicated. Secondly, the holding torque for one step is reduced by the mini-stepping factor. In other words, for×10 mini-stepping, it takes only 1/10 of the full-step holding torque to cause the motor to have a positioning error equivalent to one step (a mini-step).

To clarify a little what that means, lets take a look at the torque produced by a stepper motor. For simplicity, lets consider the case of a single phase being energized (**Fig. 4.36**).

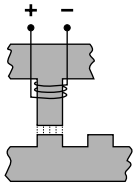

Fig. 4.36—Single Phase Energization

Once the closest rotor tooth has been pulled in, assuming that there is no external load, the motor does not develop any torque. This is a stable point.

If external forces try to move the rotor (**Fig. 4.37**), the magnetic force will pull back the tooth. The more teeth misalignment exists, the larger the generated torque.

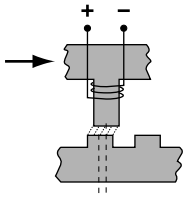

Fig. 4.37—External Force Applied

If the misalignment keeps increasing, at some point, the torque peaks and then starts diminishing again such that, when the stator is exactly between the rotor teeth, the torque becomes zero again (**Fig. 4.38**).

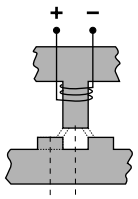

Fig. 4.38—Unstable Point (Potential Step Error)

This is an unstable point and any misalignment or external force will cause the motor to move one way or another. Jumping from one stable point to another is called *missing steps*, one of the possible disadvantages of stepper motors.

The torque diagram versus teeth misalignment is shown in**Fig. 4.39**. The maximum torque is obtained at one quarter of the tooth spacing, which is equivalent to one full step.

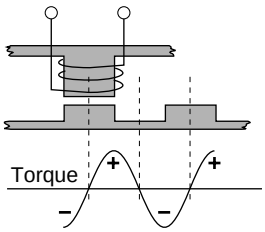

Fig. 4.39—Torque and Tooth Alignment

This torque diagram is accurate even when the motor is driven with half-, mini- or micro-steps. The maximum torque is still one full step away from the stable (desired) position. When mini- and micro-stepping motors are used in open-loop applications there is an inherent error due to possible loss of steps. But, advanced controllers like the MM3000 can control the stepper motors with closed loop operation to eliminate this problem.

Advantages

Stepper motors are primarily intended to be used for low cost, microprocessor controlled positioning applications. Due to some of their inherent characteristics, they are preferred in many industrial and laboratory applications. Some of their main advantages are:

— low cost full-step, open loop implementation

— no servo tuning required

— good position lock-in

— no encoder necessary

— easy velocity control

— retains some positioning torque even with power off

— no wearing or arcing commutators

Disadvantages

Some of the main disadvantages of the stepper motors are:

— could loose steps (synchronization) in open loop operation

— requires current (dissipates energy) even at stop

— Generates higher heat levels than other types of motors

— moves from one step to another are made with sudden motions

— large velocity ripples, especially at low speeds, causing noise and possible resonances

— load torque must be significantly lower than the motor holding torque to prevent stalling and missing steps

— limited high speed

4.6.2 DC Motors

A DC motor is similar to a permanent magnet stepper motor with an added internal phase commutator (**Fig. 4.40**).

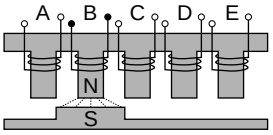

Fig. 4.40—DC Motor

Applying current to phase B pulls in the rotor pole. If, as soon as the pole gets there, the current is switched to the next phase (C), the rotor will not stop but continue moving to the next target. Repeating the current switching process will keep the motor moving continuously. The only way to stop a DC motor is not to apply any current to its windings. Due to the permanent magnets, reversing the current polarity will cause the motor to move in the opposite direction.

Of course, there is a lot more to the DC motor theory but this description gives a general idea on how they work. A few other characteristics to keep in mind are:

— for a constant load, the velocity is approximately proportional to the voltage applied to the motor

— for accurate positioning, DC motors need a position feed-back device

— constant current generates approximately constant torque

— if DC motors are turned externally (manually, etc.) they act as generators

Advantages

DC motors are preferred in applications that require:

— smooth, ripple-free motion at any speed

— high torque per volume

— no risk of loosing position (in a closed loop)

— higher power efficiency than stepper motors

— no current requirement at stop

— higher speeds can be obtained than with other types of motors

Disadvantages

Some of the DC motor's disadvantages are:

— requires a position feedback encoder and servo loop controller

— requires servo loop tuning

— commutator may wear out in time

— not suitable for high vacuum application due to the commutator arcing

4.7 Drivers

Motor drivers must not be overlooked when evaluating a motion control system. They represent an important part of the loop that in many cases could increase or reduce the overall performance.

The MM3000 is an integrated controller and driver. The controller part is common for any configuration but the driver section must have the correct hardware for each driven motor. The *driver hardware* is one driver card per axis and one interface card that install easily in the rear of the controller. Always make sure that the motor specified on the driver card label matches the label on the motion device.

There are important advantages to having an integrated controller/driver. Besides reducing space and cost, integration also offers tighter coordination between the two units so that the controller can more easily monitor and control the driver's operation.

Driver types and techniques vary widely, in the following paragraphs we will discuss only those implemented in the MM3000.

4.7.1 Stepper Motor Drivers

Driving a stepper motor may look simple at first glance. For a motor with four phases, the most widely used type, we need only four switches (transistors) controlled directly by a CPU (**Fig. 4.41**).

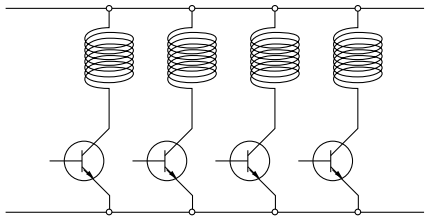

Fig. 4.41—Stepper Motor Phase Switching

This driver works fine for simple, low performance applications. But, if high speeds are required, having to switch the current fast in inductive loads becomes a problem. When voltage is applied to a winding, the current (and thus the torque) approaches its nominal value exponentially (**Fig. 4.42**).

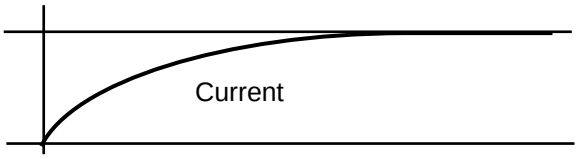

Fig. 4.42—Voltage vs Current of Motor Pulse

When the step pulse rate is fast, the current does not have time to reach the desired value before it is turned off and the total torque generated is only a fraction of the nominal one (**Fig. 4.43**).

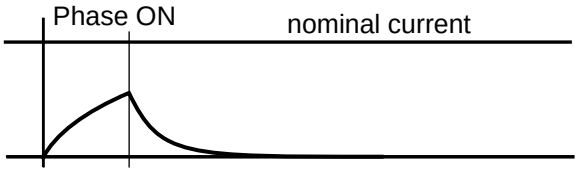

Fig. 4.43—Effect of High Pulse Speed on Current

How fast the current reaches its nominal value depends on two factors: the winding's inductance and resistance and the voltage applied to the winding.

The inductance cannot be changed. But the voltage can be temporarily increased to bring the current to its desired level faster. The most widely used technique is a high voltage chopper.

If, for instance, a stepper motor requiring only 3V to reach the nominal current is connected momentarily to 60V, it will reach the same current in about 1/10 of the time (**Fig. 4.44**).

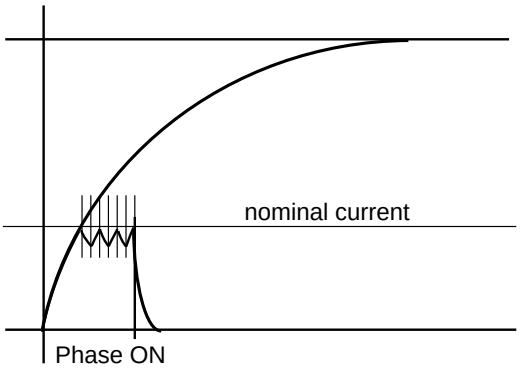

Fig. 4.44—Motor Pulse with High Voltage Chopper

Once the desired current value is reached, a chopper circuit activates to keep the current close to the nominal values.

The MM3000 uses three implementations of this circuit for two different driver card families. One of them, PIN **40000N**, is designed for small variable-reluctance motors and offers only full-stepping capabilities. It can drive the following motors:

MOTOR	MODE	CURR. (A)	VOLT. (V)
UE30PP	full-step	0.20	60

The other type of driver card is PIN **40002**. It is designed to drive four phase permanent motors. The different configurations are for the following motors:

MOTOR	MODE	CURR. (A)	VOLT. (V)
UE16PP	half-step	0.2	60
UE31PP	full-step	0.4	60
UE32PP	×10 mini-step	1.0	60
UE41PP	×10 mini-step	1.0	60
UE72PP	×10 mini-step	1.6	60

Additionally, several motors can be operated in micro-step (x100). Call Newport for details.

4.7.2 DC Motor Drivers

There are three major categories of DC motor drivers. The simplest one is a voltage amplifier (**Fig. 4.45**).

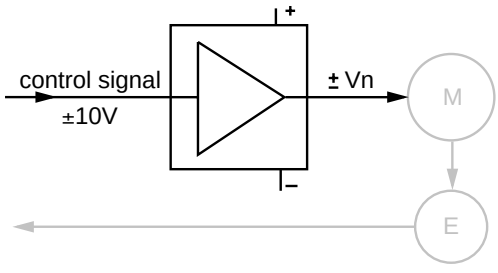

Fig. 4.45—DC Motor Voltage Amplifier

The driver amplifies the standard ±10V control signal to cover the motor's nominal voltage range while also supplying the motor's nominal current.

This type of driver is used mostly in low cost applications where following error is not a great concern. The controller does all the work in trying to minimize the following error but load variations make this task very difficult.

The second type of DC motor driver is the current driver, also called a torque driver (**Fig. 4.46**).

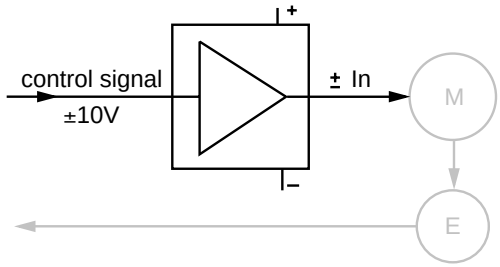

Fig. 4.46—DC Motor Current Driver

In this case, the control signal voltage defines the motor current. The driver constantly measures the motor current and always keeps it proportional to the input voltage. This type of driver is usually preferred over the previous one in digital control loops, offering a stiffer response and thus reduces the dynamic following error.

But, when the highest possible performance is required, the best choice is always the velocity feedback driver. This type of driver requires a tachometer, an expensive and sometimes difficult to add device **(Fig. 4.47**).

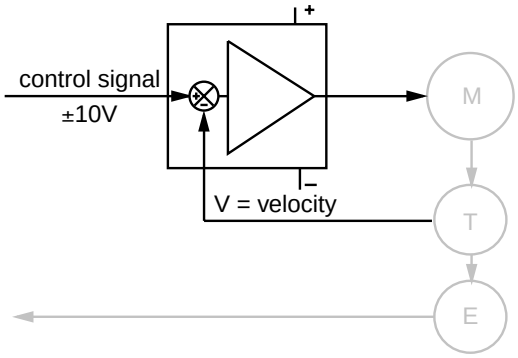

Fig. 4.47—DC Motor Velocity Feedback Driver

The tachometer, connected to the motor's rotor, outputs a voltage directly proportional with the motor velocity. The circuit compares this voltage with the control signal and drives the motor so that the two are always equal. This creates a second closed loop, a velocity loop. Motions performed with such a driver are very smooth at high and low speeds and have a smaller dynamic following error.

General purpose velocity feedback drivers have usually two adjustments: *tachometer gain* and *compensation* (**Fig. 4.48**).

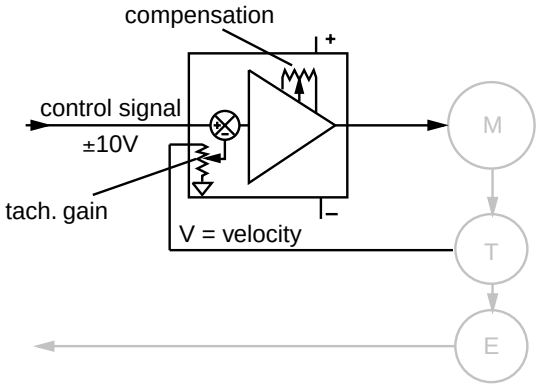

Fig. 4.48—DC Motor Tachometer Gain and Compensation

The *tachometer gain* is used to set the ratio between the control voltage and the velocity. The *compensation* adjustment reduces the bandwidth of the amplifier to avoid oscillations of the closed loop.

Some of the MM3000 drivers use this type of velocity feedback loop circuitry.

Each driver card is configured with fixed components for a particular motor and is identified as such with a label on the rear panel. This means that a driver card can be used only with the specified motor. Another motor, even one with similar parameters, will not work.

The voltage and current marked on the label are not the actual values used by the motor. They represent the limits set by the driver and often the motor uses only a fraction of them.

The MM3000 uses two types of DC motor drivers, one for low-power motors and one for high-power motors. The first one can drive the following small motors:

MOTOR	VOLT. (V)	CURR. (A)
UE16CC	12	0.1
UE30CC	24	0.15
UE31CC	24	0.15
UE33CC	24	0.3

The second type of driver card is used for larger DC motors:

MOTOR	VOLT. (V)	CURR. (A)
UE404CC	30	0.9
UE506CC	30	1.2
UE511CC	30	2

Section 5
Servo Tuning

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Section 5 — Servo Tuning

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Section 5
Servo Tuning

5.1 Servo Tuning Principles

In the MM3000 controller, the servo loop is of the type called PID.*Servo Tuning*, in this manual, means setting the **Kp**, **Ki, IL** and **Kd** parameters of the digital PID algorithm, also called the PID filter.

Tuning PID parameters requires a reasonable amount of closed loop systems understanding. Please review the **Control Loops** paragraph in the **Motion Control Tutorial Section** and, if needed, consult additional servo control theory books.

Always start the tuning process using the default values supplied with the MM3000 for each motion device type. These values are usually very conservative, favoring a safe, oscillation free operation for a *tighter*, more responsive system that minimizes following error. To achieve good dynamic performance, the system must be tuned for a specific application. Load, acceleration, stage orientation and performance requirements all affect how the servo loop should be tuned for best results.

Hardware Requirements

Tuning is best accomplished when the system response can be measured. This can be done with external position measurement devices but this method can introduce errors. Therefore, the MM3000 controller offers a **Trace** capability. When **Trace** mode is activated, the controller records the real and desired positions, which are the basic pieces of information that are needed to determine the PID filter. The sample interval can be as fast as 100µsec and the total sample can be up to 1000 points.

With these powerful capabilities, there is no need for additional hardware to perform servo tuning.

Software Requirements

Trace mode is supported by the TR and TT commands.

The sampled data data for tuning can be aquired two ways: using custom software that implements the commands mentioned or using the supplied PROFILE program that has all the necessary functions.

For a detailed description of the PROFILE program and its operation please review the SOFTWARE User's Manual.

5.2 Tuning Procedures

There are two common reasons to perform servo tuning: a) better motion performance (to reduce the following error, statically and/or dynamically) and b) a malfunctioning system (oscillating and/or shutting off power due to excessive following error.)

Acceleration plays a significant role in the magnitudes of the following error and the overshoot, especially at start and stop. Asking the controller to change the velocity instantaneously amounts to an infinite acceleration which, since it's physically impossible, causes large following errors and overshoot. Use the smallest acceleration the application can tolerate to reduce overshoot and make tuning the PID filter easier.

NOTE

In the following descriptions, it is assumed that some kind of software utility (e.g., PROFILE) is being used to capture the response of the servo loop and to visualize the results.

5.2.1 Axis Oscillation

An oscillating axis indicates that the **Kp** gain may be too large. Start by reducing the proportional gain factor **Kp** by one order of magnitude (e.g. 100 to 10) and setting **Ki** and **Kd** to zero.

NOTE

Remember that the default values set with TY command are conservative enough to guarantee oscillation free operation. See Appendix C for parameters.

If the oscillation does not stop, reduce the **Kp** again.

NOTE

The first step should be sufficient to eliminate oscillation. If not, it may indicate the existence of other problems, usually with the hardware (wiring, etc.)

When the axis stops oscillating, the system response is probably very *soft*, i.e., the following error may be quite large during motion and the desired position might not equal the actual position at stop. It is recommended to continue tuning the PID with the steps described in the next paragraph.

5.2.2 Increasing Performance

If the system is stable but improved performance is desired, start with the default parameters (see Appendix C). The goal is to reduce the following error during motion and to eliminate it at stop.

Depending on the desired performance, here are some guidelines for further tuning.

Following Error Too Large

This is often refered to as a *soft* loop. It is especially common if the steps in 5.2.1 were performed. The proportional gain **Kp** is probably too low and **Ki** and **Kd** are zero (or close to 0).

Start by increasing **Kp** by a factor of 1.5 to 2. Repeat doubling **Kp** while monitoring the following error until it starts to exhibit excessive *ringing* characteristics (more than 3 cycles after stop.) To reduce ringing, add some damping by increasing the **Kd** parameter.

Start with a **Kd** value of 10. Increase it by a factor of 2 while monitoring the following error. As **Kd** is increased, the overshoot and the ringing decrease almost to zero. If **Kd** is further increased, at some point the oscillation will reappear, usually at a higher frequency. Avoid this by keeping **Kd** at a high enough value without reintroducing oscillations.

Next, increase the **Kp** value by 50% at a time until signs of excessive ringing appear again.

Repeat increasing **Kd** and **Kp** alternatly until **Kd** cannot eliminate the overshoot and ringing at stop. This indicates **Kp** is larger than its optimal valve and should be reduced.

Which **Kp** and **Kd** should ultimately be used depends on how *stiff* the closed loop should be and how much *ringing* is tolerable.

Errors At Stop (Not In-Position)

If the dynamic response of the PID loop is satisfactory but the motion device does not always stop at the desired position, modify the integral gain factor **Ki** and the integration limit **IL**. As described in the **Motion Control Tutorial** section, this term of the PID filter reduces the following error. Unfortunately, it can also contribute to oscillation and overshoot. Always change this parameter carefully and in conjunction with **Kd**.

Start, if possible, with a value for **Ki** that is at least two orders of magnitude smaller than **Kp**. Increase its value by 50% at a time and monitor the overshoot and the final position at stop. Also increase **IL** along with **Ki** (make it approximately the same as **Ki**).

If intolerable overshoot develops, increase the **Kd** factor. Continue increasing **Ki**, **IL** and **Kd** alternately until an acceptable loop response is obtained. If oscillation develops, immediately reduce **Ki** and **IL**.

Remember that any finite value for **Ki** will *eventually* reduce the error at stop. It is simply a matter of how much time is acceptable for your application. In most cases it is preferred to wait a few extra milliseconds to stop in position rather than have overshoot or run the risk of oscillations.

Following Error During Motion

This is caused by a too small **Ki** and **IL** value. Follow the steps in the previous paragraph, keeping in mind not to increase the integral gain factor more than required by the application.

5.2.3 Points To Remember

— Use PROFILE to change the PID parameters and to visualize the effect. Always compare the results and the parameters used with the previous iteration.

— The MM3000 controller uses a servo loop based on the PID.

— Use the lowest acceleration the application can tolerate. Smaller acceleration means less overshoot.

— Use the default values provided with the system for all standard motion devices as a starting point.

— Use the minimum value for **Ki** and **IL** that give acceptable performance. The integral gain factor can cause overshoot and oscillations.

5.3 Using PROFILE Utility

The PROFILE software supplied with the controller is a comprehensive utility that provides a powerful environment for servo tuning. Its main advantages are that it performs all necessary aquisitions automatically and offers graphs of both desired and actual positions.

The program is written for DOS environment.

A detailed description of its functions and operation is included in the **Software Utilities User's Manual**.

Section 6
Optional Equipment

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Section 6 — Optional Equipment

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Section 6
Optional Equipment

6.1 Joystick

The optional MM3000 Joystick allows manual control of up to four axes.

6.1.1 Description of Joystick

To control motion, the joystick outputs four analog signals to the MM3000 analog to digital inputs channel 1 to 4. These analog signals are interpreted as direction and speed control commands.

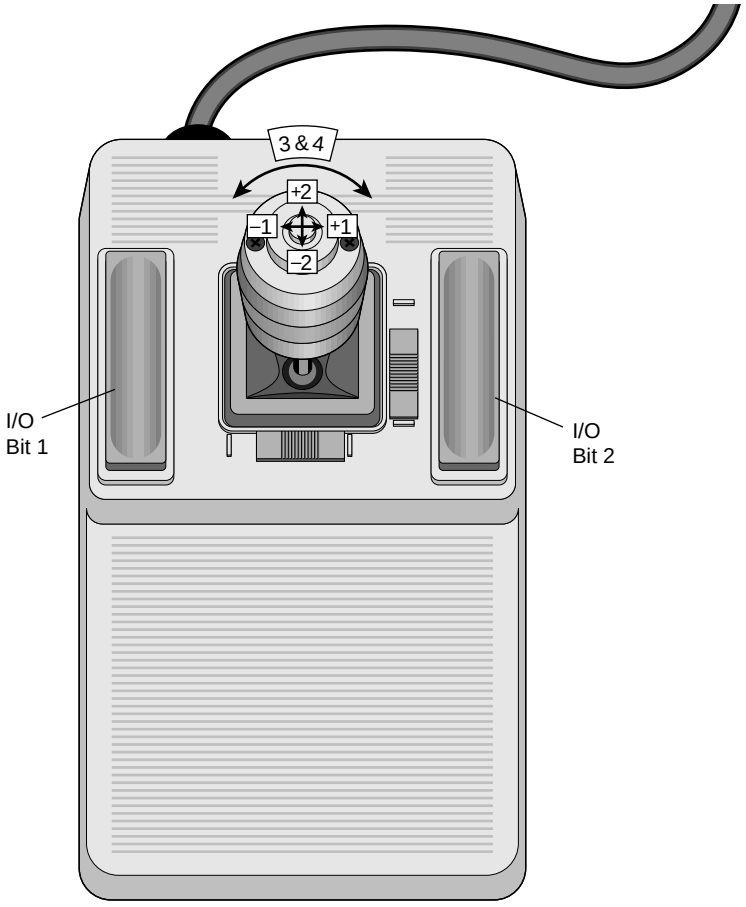


Fig. 6.1—Joystick

Internally, three potentiometers and three switches make up the joystick. The output of the axis 1 potentiometer is routed to Channel 1 A/D input (pin 1 on the GPIO). The output of the axis 2 potentiometer is routed to Channel 2 A/D input (pin 2 on the GPIO).

The third potentiometer resides in the bulb of the handle. It is actuated by twisting the bulb clockwise and counterclockwise. The output of this potentiometer is multiplexed to Channel 3 and Channel 4 A/D inputs (pin 3 and 4 on the GPIO, respectively). The multiplexing operation is selected with the switch on top of the handle. On power up, the potentiometer output is routed to Channel 3 A/D input. Pressing the switch once routes the output to Channel 4 A/D input. Pressing the switch again routes the output back to Channel 3 A/D input, etc.

On the left and right side of the joystick are two long rectangular switches. The left switch is routed to Programmable I/O Bit 1. The right switch is routed to Programmable I/O Bit 2. When either switch is pressed, it outputs a high signal. These switches may be used to control the MM3000IF/THEN, WHILE/WEND, and WB (wait bit) commands. In addition, they may be used with the RB command.

NOTE

When the joystick is used, GPIO A/D Channel 1–4 (Pin 1–4) and I/O Bit 1 and 2 (Pin 24 and 25) can not be used for other purposes.

6.1.2 Joystick Set-Up

1. Switch off power on the MM3000. Connect the joystick to the MM3000 JOYSTICK connector. Secure the connection by tightening the two screws on the joystick connector.

2. Joystick Axis — Motor Axis Assignments

   The user has to assign a joystick axis to each MM3000 motor axis to be controlled. Any permutation is allowed. The assignment can be performed in two ways: a) sending the JY command or b) through the front panel menu (local mode).

NOTE

When assigning axes, the joystick must be at the center position because the MM3000 calibrates the zero position of the joystick at this point.

a) Using the JY command

Example 1: ***1JY1;2JY2;3JY3;4JY4***

Sending these commands to the MM3000 causes motorAXIS 1 to be controlled by Channel 1 A/D input (axis 1 on the joystick), motorAXIS 2 to be controlled by Channel 2 A/D input (axis 2 on the joystick), motor AXIS 3 to be controlled by twisting the knob on the joystick handle and motor AXIS 4 to be controlled by twisting the knob on the joystick handle after the button on top of the knob has been pressed once.

Example 2: ***1JY3;2JY1;3JY4;4JY2***

Here, motor AXIS 1 is to be controlled by Channel 3 A/D input (twisting knob), motor AXIS 2 is to be controlled by Channel 1 A/D input (1-axis on the joystick), and so on.

Example 3: ***1JY1;2JY1***

Motor AXIS 1 and motor AXIS 2 are to be controlled simultaneously by Channel 1 A/D input (axis 1 on the joystick).

Example 4: ***1JY-1;2JY-3***

Sometimes the orientation of the positioning system and the joystick may not provide an intuitive feel for motion direction, i.e., moving the joystick handle forward may cause a stage to move backwards. This can be corrected as shown above.

These commands tell the MM3000 that motorAXIS 1 is to be controlled by Channel 1 A/D input (axis 1 on the joystick) and that+1 actuation of the joystick causes a negative direction motion. In addition, motor axis 2 is to be controlled by Channel 3 A/D input (rotation-axis on the joystick) and that a clockwise twist of the handle causes a negative direction motion.

b) Axis assignment in Local Mode

For instructions on how to assign axes in Local Mode, refer to to Section 2.

NOTE

After setup is performed, switch on the motor with MO command or through the front panel menu to enable proper joystick operation.

6.1.3 Setting Speeds

The maximum speed for axes 1 and 2 (i.e., when the joystick handle is thrown to either extreme position) is set with theVA command. Either send the VA command through one of the MM3000 remote interfaces or use the *Set Vel* menu item in Local Mode (see Section 2).

The maximum speed for the joystick rotation axis is also set with theVA command. However, the actual speed will be about **one-third** of the programmed value. To check the actual speed during a joystick move, use the TV command.

NOTE

Speeds can only be set when the joystick is at rest.

6.2 Hand-held Keypad

An optional alphanumeric keypad (see below) allows the user to access the full command set of the MM3000 without the use of a host terminal (e.g., computer). The keypad features a backlit LCD display that echoes each character typed on the keypad. Additionally, status messages are echoed to the display in certain cases (e.g., error codes).

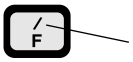
Four macro keys on the top row of the keypad permit execution of previously programmed macros on the push of one button (seeEM, CM, RM commands in the Command Section for details).

Description of Keys

When this button is activated, all motion is aborted and motor power disabled. All axes are affected. The function of STOP ALL on the keypad is equivalent to STOP ALL on the MM3000 front panel.

Activating either MACRO button results in execution of a previously stored macro. See CM command in Section 3 for details on programming macros.

Pressing this key in connection with a double function key selects the upper symbol, e.g.



When this key is pressed, all previously typed characters are sent to the MM3000.

Pressing this key deletes a preceding character. Pressing it in connection with the SHIFT key inserts a space in a given line.

6.2.1 Activating the Keypad

NOTE

**Switch the MM3000 off before connecting the keypad!
At power-up, the MM3000 automatically detects the presence of the keypad.**

Plug one end of the cable that was supplied with the keypad into the receptable on the bottom side of the keypad and the other end into the receptable on the lower left corner of the MM3000 front panel. The MM3000 will detect the presence of the keypad after power-up and configure itself for proper operation. No user settings are required. After power up, the keypad should show the following message:

"NEWPORT CORP., MM3000, VER. X.X"

Now, the keypad is ready for use. An easy way to verify proper operation of the keypad is by sending the VE command (type: VE and hit ENTER). The MM3000 should respond with the current version.

Section 7
D/A and A/D Converter

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Section 7
D/A and A/D Converter

7.1 Analog to Digital (A/D) Converter

The MM3000 provides an 8 channel 10-bit analog to digital converter. It will convert any analog voltage up to 9 volts into a numerical number. TheRA command is used to direct the MM3000 to convert the voltage at the specified channel and respond with a numerical equivalent.

A/D Block Diagram

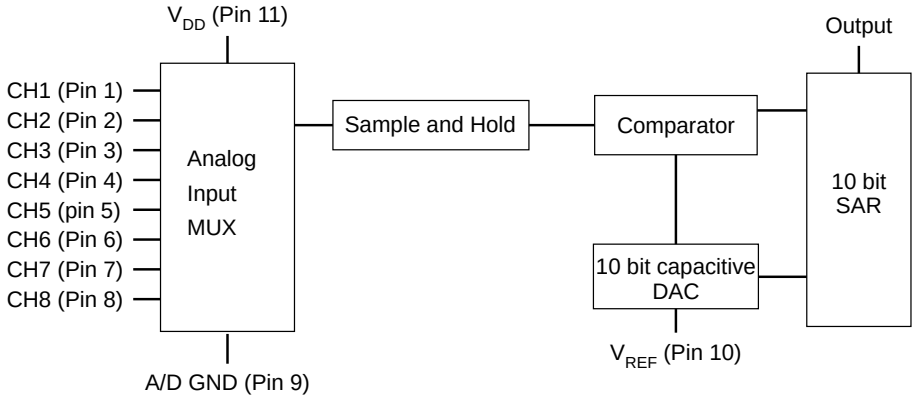


Fig. 7.1—Internal Block-Diagram

The input pins CH1 - CH8, V_{DD}, A/D GND, and V_{REF} are accessed on the General Purpose I/O connector. See Appendix B for pinouts. The output is obtained with the RA command.

Conversion Specifications

- The conversion formula is:

  digital output = (V sample/V_{REF}) •1023

  LSB = V_{REF} /1024
  Total Error = ± 0.5LSB

- When Vsample equals V_{REF}, the output is full scale, which is 1023.

- Conversion Time: 1 millisecond.
  This includes the time for the MM3000 to interpret the command and perform the A/D conversion.

Voltage Requirements

- V_{DD} is the A/D converter supply voltage (pin 11 of GPIO connector):
  Minimum value = 5V
  Maximum value = 10V

- V_{REF} (pin 10 of GPIO connector):
  Minimum value = 0V
  Maximum value = 10V
  Source Impedance must be less than 10 ohms. Use low impedance OP-AMP or a power supply (e.g., 5V from GPIO connector).

NOTE

V_{REF} and the sample voltage inputs must always be less than or equal to the power supply voltage V_{DD}.

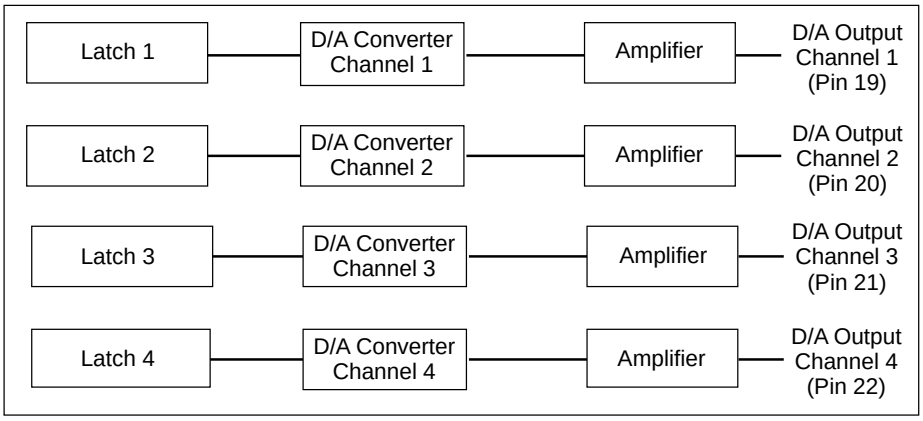
Normally V_{REF} should be equal to the largest sample voltage that will be converted. However, V_{REF} may be smaller than the sample voltage to obtain higher resolution at a selected portion of the sample voltage.

- CH1 - CH8 sample voltage inputs:
  Minimum value = 0V
  Maximum value = 9V
  Source Impedance less than 1kOhm. Use low impedance OP-AMP.

7.2 Digital to Analog (D/A) Converter

The MM3000 provides an optional 4 channel digital to analog converter with 8-bit resolution. It will convert a numerical value to an analog voltage up to 9 volts. The WD command is used to direct the MM3000 to convert the specified numerical parameter of the command to a corresponding analog voltage.

D/A Block Diagram



The output pins are accessed on the General Purpose I/O connector. See Appendix B. The output voltage is set with the WD command (see Command Section for details).

Conversion Specifications

- The conversion formula is:

  voltage out = 10 • (WD parameter/256)

  One LSB = 10/256
  Total Error = ± 2LSB

  See WD command.

- The output amplifiers can source and sink 5 milliamps.
- The maximum output voltage is 9 Volts.

Appendices


Newport Motion Controller Model MM3000
NO STAGE
+0
+100365
RESET
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Appendix A
Error Messages

The MM3000 has an elaborate command interpreter and system monitor. Every command is analyzed for syntax and correct format after it is received. The result of the analysis is stored in an output buffer. During moves and while idle, system inputs are monitored and any change is reported to the user via the output buffer. To read the contents of the output buffer, send the command TB (tell buffer) and then read the response string.

For faster and more compact error reads, use the TE command. The MM3000 response to this command is a one byte, binary coded error number.

Below is a listing of all possible MM3000 messages.

E00 NO ERROR
Command received is correct and will be executed.

E01 BAD COMMAND
Command does not exist in the MM3000 command set.

E02 ILLEGAL PARAMETER
Parameter field contains non-numeric character or numeric parameter out of range.

E03 COMMUNICATION TIMEOUT
A communication transfer from the MM3000 to host computer was initiated and never completed.

E04 MODULE NOT PRESENT
Command sent to a module which is not installed in the MM3000.

E05 COMMAND/MODULE MISMATCH
A stepping motor specific command sent to a DC motor, or a DC motor specific command sent to a stepping motor.

E06 MOTOR DRIVERS DISABLED
Check if Motor Interlock connector is properly configured (see Appendix B).

E07 MOTOR NOT CONNECTED
Motion command sent to a motor which is not connected.

E08 AXIS 1 MOTOR FOLLOWING ERROR
The present real position of the motor connected to axis 1 is lagging the present desired position by more encoder counts than specified with the FE command.

E09 AXIS 2 MOTOR FOLLOWING ERROR

The present real position of the motor connected to axis 2 is lagging the present desired position by more encoder counts than specified with the FE command.

E10 AXIS 3 MOTOR FOLLOWING ERROR

The present real position of the motor connected to axis 3 is lagging the present desired position by more encoder counts than specified with the FE command.

E11 AXIS 4 MOTOR FOLLOWING ERROR

The present real position of the motor connected to axis 4 is lagging the present desired position by more encoder counts than specified with the FE command.

E12 MACRO ALREADY EXIST

A macro with the same number as an already existing one can not be created. First erase the old macro, then create the new one (see RM command).

E13 EMERGENCY STOP ACTIVATED

An emergency stop was executed because the MM3000 received the # character, the STOP ALL button was pressed, or the motor interlock on the rear of the MM3000 was activated.

E14 INSUFFICIENT MEMORY

The MM3000 program memory is full. No more commands can be stored.

E15 MACRO NOT FOUND

The execute macro command (EM) was sent or a Macro key on the keypad was pressed with a macro number which does not exist.

E16 MISSING PROGRAM

There is no program to execute.

E17 PROGRAM NOT COMPILED

The execute program command (EX) was sent, but there are errors in the program.

E18 REPEAT FAILURE

A carriage return was sent to repeat last command. However, no valid command exists for repeat execution.

E19 NOT ALLOWED IN PROG EXECUTION MODE

Command or command sequence not allowed in program mode

E20 TARGET LABEL NOT IN PROGRAM

The JL command in a program references a undefined label.

E21 REDEFINED LABEL

The same DL label exists in more than one position in a program.

E22 EXECUTABLE ONLY WITHIN PROGRAM

Command or command sequence can only be executed in program mode. Cannot be executed in immediate command execute mode.

E23 COMMAND LINE EXCEEDS 80 CHARACTERS

The single line sequence of commands entered contains more than 80 characters.

E24 PARAMETER OUT OF RANGE
The parameter specified is out of the boundary range set.

E25 INTERNAL COMMUNICATION ERROR
The communication between the MM3000 master and slave processors has an error.

E26 RS232 ERROR
An RS-232-C framing error or overrun error exist. The RS-232-C communication parameters may be incorrect.

E27 RECEIVER BUFFER FULL
The 512 byte command input buffer is full. Wait commands likeWS and WP are halting command processing so there is no room for new commands.

E28 STORED PROGRAM CORRUPTED
The battery backed RAM has been erased or written over with bad data.

E29 SYSTEM IS BUSY
For stepping motor: Move or acceleration command sent to an axis which is presently executing a previous move command.

For DC motor: Acceleration command sent to an axis which is presently executing a move command.

E30 NESTED WHILE/WEND NOT PERMITTED
See Command Section.

E31 WEND WITHOUT WHILE FOUND
See Command Section.

E32 WHILE WITHOUT WEND FOUND
See Command Section.

E33 ENCODER FEEDBACK NOT ENABLED
Encoder must be enabled for closed loop stepper operation (CL command). See FM command.

E34 INTERNAL FAILURE
Internal hardware or software error.

E35 AXIS 1 NEGATIVE HARD LIMIT
The MM3000 has sensed a high level at its negative travel limit input. It will interpreter this as reaching a negative travel limit.

E36 AXIS 2 NEGATIVE HARD LIMIT

E37 AXIS 3 NEGATIVE HARD LIMIT

E38 AXIS 4 NEGATIVE HARD LIMIT

E39 AXIS 1 POSITIVE HARD LIMIT

E40 AXIS 2 POSITIVE HARD LIMIT

E41 AXIS 3 POSITIVE HARD LIMIT

E42 AXIS 4 POSITIVE HARD LIMIT

E43 AXIS 1 NEGATIVE SOFT LIMIT
Command directs the MM3000 to move past a previously defined position set as the soft limit with the SL command.

E44 AXIS 2 NEGATIVE SOFT LIMIT

E45 AXIS 3 NEGATIVE SOFT LIMIT

E46 AXIS 4 NEGATIVE SOFT LIMIT

E47 AXIS 1 POSITIVE SOFT LIMIT

E48 AXIS 2 POSITIVE SOFT LIMIT

E49 AXIS 3 POSITIVE SOFT LIMIT

E50 AXIS 4 POSITIVE SOFT LIMIT

E51 AXIS 1 JOYSTICK SOFT LIMIT

E52 AXIS 2 JOYSTICK SOFT LIMIT

E53 AXIS 3 JOYSTICK SOFT LIMIT

E54 AXIS 4 JOYSTICK SOFT LIMIT

E55 STAGE RESOLUTION NOT DEFINED
Stage resolution was not defined with US command.

E56 UNITS NOT DEFINED
Positioning unit not defined with UU command.

E57 UNITS/STAGE MISMATCH
Rotary units can only be used for rotary stages.
Linear units can only be used for linear stages.
See US and UU commands.

Appendix B
Connector Pinouts

Labeling Conventions

All pinout diagrams in this section use the following labeling convention:

GND ⇒ ground

N.C. ⇒ Not connected

UTIL ⇒ Test and/or utility signal. **DO NOT USE**; some pins **may be energized**.

I ⇒ Input

O ⇒ Output

Motor Interlock Connector (9-Pin, D-Sub)

This connector is provided for the wiring of one or more remote Motor Interlock switches. They will have an effect similar to the front panel **STOP ALL** button.

Switches that are used should have normally closed contacts. If more than one switch is installed, they should be connected in series. The minimum rating for the switches should be **500mA** at **5V**.

Pin #		Description
1	—	**N.C.**
2	—	**+5V**
3	—	**INTERLOCK**
4	—	
5	—	**N.C.**
6	—	**GND**
7	—	**GND**
8	—	**GND**
9	—	**N.C.**

Emergency Stop, must always be connected to GND (Pin 6, 7, or 8) during normal controller operation. An open circuit will not allow any further motion.

A high going edge (0–5V) is equivalent to the STOP ALL button on the front panel.

GPIO Connector (37-Pin D-Sub)

The MM3000 features this 37 pin input - output connector for access to its auxiliary signals. These signals provide the ability to interact with and control the environment of a motion control system.

Pin #		Description
1	—	**Channel 1 A/D Input** (10 bit resolution)
2	—	**Channel 2 A/D Input** (10 bit resolution)
3	—	**Channel 3 A/D Input** (10 bit resolution)
4	—	**Channel 4 A/D Input** (10 bit resolution)
5	—	**Channel 5 A/D Input** (10 bit resolution)
6	—	**Channel 6 A/D Input** (10 bit resolution)
7	—	**Channel 7 A/D Input** (10 bit resolution)
8	—	**Channel 8 A/D Input** (10 bit resolution)
9	—	**A/D GND**
10	—	**A/D Reference voltage**
11	—	**A/D V_{DD} input** (supply voltage for A/D converter)
12	—	**N.C.**
13	—	**N.C.**
14	—	**N.C.**
15	—	**N.C.**
16	—	**N.C.**
17	—	**N.C.**
18	—	**UTIL.**
19	—	**Channel 1 D/A output** (8 bit resolution) *optional*
20	—	**Channel 2 D/A output** (8 bit resolution) *optional*
21	—	**Channel 3 D/A output** (8 bit resolution) *optional*
22	—	**Channel 4 D/A output** (8 bit resolution) *optional*
23	—	**D/A GND**
24	—	**Programmable TTL I/O, bit 1**
25	—	**Programmable TTL I/O, bit 2**
26	—	**Programmable TTL I/O, bit 3**
27	—	**Programmable TTL I/O, bit 4**
28	—	**Programmable TTL I/O, bit 5**
29	—	**Programmable TTL I/O, bit 6**
30	—	**Programmable TTL I/O, bit 7**
31	—	**Programmable TTL I/O, bit 8**
32	—	**- 12 V**
33	—	**+ 12 V**
34	—	**+ 5 V**
35	—	**GND**
36	—	**System Reset**
37	—	**N.C.**

Signal Descriptions

Channel n A/D input (10-bit) [Pin 1 - 8]

Connect the analog voltage (sample voltage) to be converted to these pins. The sample voltage source impedance should be less than 1KΩ, which can be established with a low output impedance OP-AMP, for example.

See Section 7 for information on the analog to digital converter.

A/D GND [Pin 9]

This is the ground reference for the sample voltage inputs. Connect the sample voltage ground to this pin.

A/D Reference Voltage [Pin 10]

This input sets the range of the converter. The voltage applied determines the full scale output of the converter, i.e., when the sample voltage equals the voltage reference, then the digital output is 1023, which is full scale.

This reference voltage input should normally be equal to the largest sample voltage. However, a smaller voltage reference at a selected portion of the sample voltage can be used to obtain higher resolution.

The source impedance of the voltage source for this input should be less than 10 ohms. Use a low impedance OP-AMP or a power supply.

A/D V_{DD} Input [Pin 11]

This is the supply voltage for the analog to digital converter. Connect an external power supply to this input or use the+5V output at pin 34.

Maximum value = 10V
Minimum value = 5V

NOTE

This voltage must be greater than or equal to the reference voltgage input and the sample voltage inputs.

UTIL. [Pin 18]

Do not connect anything to this pin.

Channel n D/A output (8 bit) [Pin 19 - 22]

These pins are the outputs of the 4 optional digital to analog converters.

Each D/A converter includes an output buffer amplifier capable of sourcing and sinking up to 5 milliamps of output current.

See Section 7 for information on the digital to analog converter.

D/A GND [Pin 23]

This pin is the ground reference point for the analog voltage outputs.

Programmable TTL I/O bit n [Pin 24 - 31]

These bits are connected directly to the internal processor and thus are bi-directional. Before a bit is used, it must be defined as an input or as an output. Use the MM3000 commands BI and BO for this purpose.

RB can be used to read the input bits and CB, SB and TG to manipulate the output bits.

Note, while some bits can be inputs, others can be outputs at the same time, i.e., the 8 bits can be split to be inputs or ouputs according to the user's requirements.

CAUTION

There is no internal electrical protection on these bits. DO NOT connect a voltage greater than +5V and less than zero volts to these bits.

Each bit can sink 2 milliamps and source 1 milliamp. It is best to externally buffer these signals. Use a transistor or any TTL chip appropriate for your application (ex. 74LS04, 7406, 7407, 74LS244, etc.)

–12 Volts [Pin 32]

–12 volt supply **output** from the internal MM3000 power supply. This output can source **100mA** max.

+12 Volts [Pin 33]

+12 volt supply **output** from the internal MM3000 power supply. This output can source **100mA** max.

+5 Volts [Pin 34]

+5 volt supply **output** from the internal MM3000 power supply. This output can source **1A** max.

GND [Pin 35]

MM3000 ground

System reset [Pin 36]

Connecting this pin to GND causes the MM3000 to reset.

RS-232C Interface Connector (9Pin D-Sub)

The RS-232 C interface uses a 9-pin Sub-D connector.

The back panel connector pinout is shown in **Fig. B.1**.

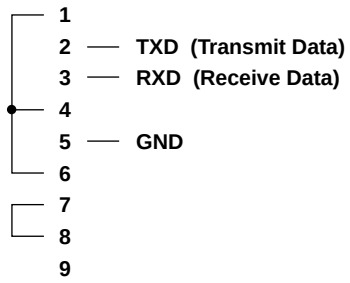


Fig. B.1—RS-232C connector pinout

RS-232C Interface Cable

The reason some pins are jumpered in the controller as described in **Fig. B.1** is to override the hardware handshake when an off-the-shelf cable is used for the RS-232-C interface. This guarantees proper communication even when the hardware handshake cannot be controlled from the communication software. **Fig. B.2** shows a simple pin-to-pin cable with 9 conductors that can be used.

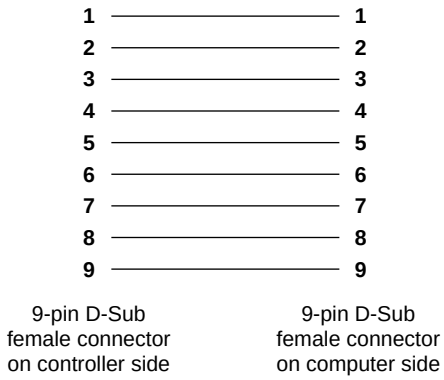


Fig. B.2—9 conductor, pin-to-pin RS-232C interface cable

A three conductor cable that connects as shown below can also be used. The jumpers on the right side might be needed to override hardware handshaking.

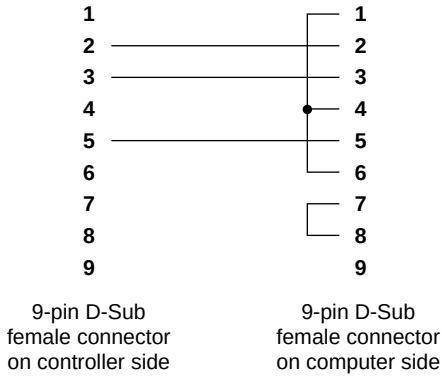


Fig. B.3—3 conductor RS-232C interface cable

If your RS232 terminal uses a 25 pin connector for the RS 232C interface, an off-the-shelf 25 to 9 pin adapter and one of the two cables described above can be utilized.

If you would like to use a three conductor cable with a 25 pin RS-232C connector and a 9 pin connector, use the wiring diagram in**Fig. B.4**.

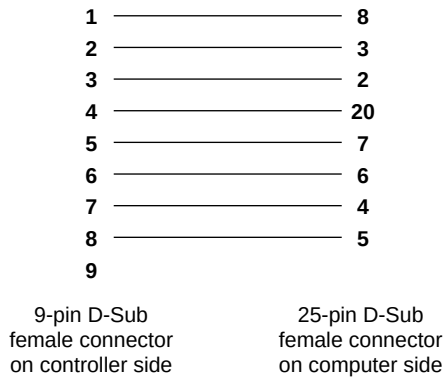


Fig. B.4—3 conductor, 9 to 25 pin RS-232C interface cable

IEEE488 Interface Connector (24Pin)

The IEEE488 connector has a standard configuration, shown in Fig.**B.5**.

	Pin #		
DIO1	1	13	DIO5
DIO2	2	14	DIO6
DIO3	3	15	DIO7
DIO4	4	16	DIO8
EOI	5	17	REN
DAV	6	18	GND
NRFD	7	19	GND
NDAC	8	20	GND
IFC	9	21	GND
SRQ	10	22	GND
ATN	11	23	GND
SHIELD	12	24	SIG. GND

Fig. B.5—IEEE488 connector definition

AXIS Connector (25-Pin D-Sub)

This connector interfaces to the motion device. Depending on the type of driver and motor, some pins have different meaning. If not otherwise specified, this description is valid for all cases.

Pin #		Stepper	DC Motor
1	**—**	Phase 1	+Tacho generator
2	**—**	Phase 1	+Tacho generator
3	**—**	Phase 2	–Tacho generator
4	**—**	Phase 2	–Tacho generator
5	**—**	Phase 3	+Motor phase
6	**—**	Phase 3	+Motor phase
7	**—**	Phase 4	–Motor phase
8	**—**	Phase 4	–Motor phase
9	**—**	Common ph. 3–4	**N.C.**
10	**—**	Common ph. 3–4	**N.C.**
11	**—**	Common ph. 1–2	**N.C.**
12	**—**	Common ph. 1–2	**N.C.**
13	**—**	Home switch signal	
14	**—**	Shield Ground	
15	**—**	Encoder index pulse I	
16	**—**	Limit Ground	
17	**—**	+ Travel limit	
18	**—**	– Travel limit	
19	**—**	Encoder channel A	
20	**—**	Encoder channel B	
21	**—**	Encoder power: +5 V or +12 V (+5 V standard)	
22	**—**	Encoder Ground	
23	**—**	Encoder channel /A	
24	**—**	Encoder channel /B	
25	**—**	Encoder index pulse /I	

Fig. B.6—Motor Pinouts

Appendix C
Compatible Motion Devices

The MM3000 controller is designed as part of a complete motion control system. The advantage is a significant improvement in performance and user friendliness due to a better match of the motion components.

MM3000 manages this by storing all necessary parameters for all motion devices in its firmware. As new motion devices are introduced in the future, new firmware versions will be released to incorporate them.

The following pages list all motion devices the MM3000 recognizes at the time of this printing. Use this list as a general reference, but remember that all necessary parameters for each device are stored in the controller's firmware and can be recalled by loading the TY(pe) values that are also listed. This is done with the MENU/SELECT on the front panel or by sending the appropriate TY command. Please refer to TY command description for details.

NOTE

Use the following motion device and parameter listing only for general reference. As new motion devices are added and improvements are made, the actual default values stored by the controller may vary from the current listing. If needed, contact Newport for an updated version.

Appendix D
Motion Program Examples

When learning a new computer language, there is no substitute for actually writing some real programs. The motion controller's command set is a specialized language that needs to be mastered in order to be able to create complex applications. To help you familiarize yourself with MM4000 programming structure and language, this appendix contains a few examples that you can read and copy.

Example I

The first example is a simple two-axes program that will generate the triangle shown in **Fig. D.1**.

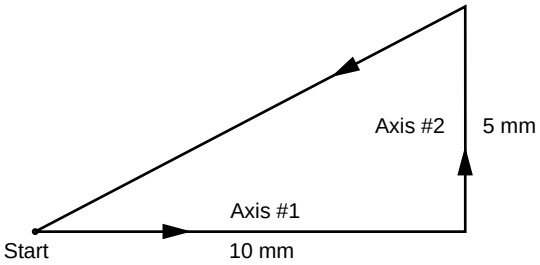
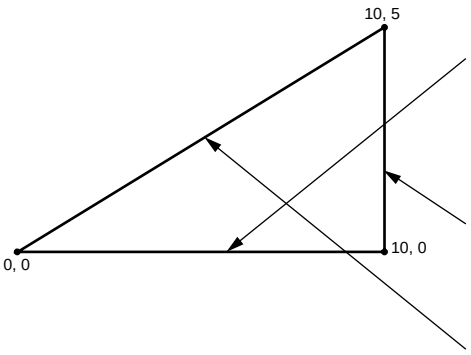


Fig. D.1— Triangle Pattern

Enter the programming mode by using the EP command.



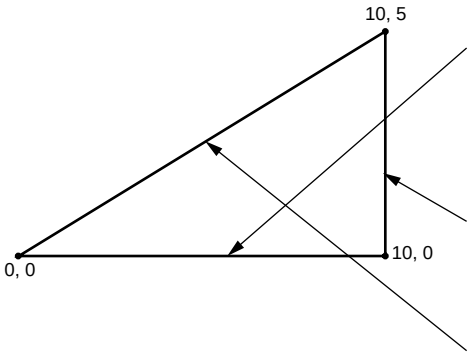
1US1.0um	*select 1 μm linear stage resolution (axis #1)*
2US1.0um	*select 1 μm linear stage resolution (axis #2)*
1UUmm	*select millimeter user units*
1EP	*enter programming mode and store all entries*
1UA50	*set acceleration of axis # 1 to 50mm/sec²*
1UV4	*set velocity of axis # 1 to 4 mm/sec*
1UP10; 1WS	*move axis # 1 to absolute position 10 mm; wait for axis # 1 to complete motion*
2UA50	*set acceleration of axis # 2 to 50mm/sec²*
2UV4	*set velocity of axis # 2 to 4 mm/sec*
2UP5; 2WS	*move axis # 2 to absolute position 5 mm; wait for axis # 2 to complete motion*
2UV2	*change velocity of axis # 2 to 2 mm/sec*
1UP0; 2UP0	*move axis # 1 to absolute position 0 mm and axis # 2 to absolute position 0 mm*
%	*end of program; quit programming mode*
CP	*compile program*
EX	*execute program*

Example II

In the previous example, to generate the diagonal line (the third motion segment) both axes must move simultaneously. This is achieved by taking two special precautions: the commands are placed on the same line to ensure a good start synchronization and the velocities are modified such that the motions will end virtually in the same time.

But, if you would measure very accurately the precision of this diagonal line, you would notice some errors due to imperfect start synchronization. In other words, we achieved this dual-axes motion with two independent single-axis motions.

To eliminate these motion errors, we need to use the axes synchronization feature. The improved program will have the following listing:



1US1.0um	*define stage resolution (axis 1)*
2US1.0um	*define stage resolution (axis 2)*
1UUmm	*select user units*
2EP	*enter programming mode and store all entries as program # 2*
1UA50	*set acceleration of axis # 1 to 50 mm/sec²*
1UV4	*set velocity of axis # 1 to 4 mm/sec*
1UP10; 1WS	*move axis # 1 to absolute position 10 mm; wait for axis # 1 to complete motion*
1UA25	*set accelertion of axis # 2 to 25 mm/sec²*
2UV2	*set velocity of axis # 2 to 2 mm/sec*
2UP5; 2WS	*move axis # 2 to absolute position 5 mm; wait for axis # 2 to complete motion*
SY1, 2	*declare axes # 1 and # 2 synchronized*
1UP0; 2UP0; SE; WA	*set axis # 1 destination to 0 mm and axis # 2 destination to 0 mm; start synchronous motion; wait for motion to complete*
SY0	*declare axes # 1 and # 2 non-synchronized*
%	*end of program; quit programming mode *
CP	*compile program*
EX	*execute program*

When finished with an interpolated motion, always return the axes to the non-synchronized mode.

Example III

The MM3000 does not offer true circular interpolation, but in many cases less demanding applications can be successfully implemented.

Take the example of dispensing glue on the pattern shown in**Fig. D.2**.

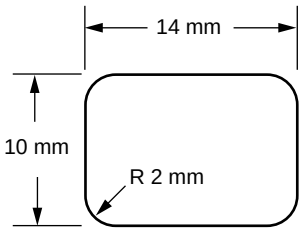


Fig. D.2— Glue Dispensing Pattern

The glue will be controlled by a TTL line and we select it to be bit number 3 of the I/O output port (see Appendix B).

To approximate this trajectory, we need to synchronize the two axes such that the acceleration of one overlaps with the deceleration of the other (**Fig. D.3**).

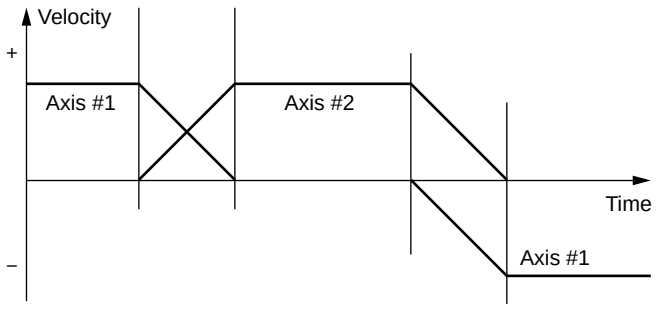


Fig. D.3—Overlapping Axis Acceleration/Deceleration

Assuming that the desired velocity is 4 mm/sec, we need to calculate the acceleration and the positions where one axis starts decelerating and the other accelerating.

Given the radius of 2 mm, we know that an axis must travel 2 mm before reaching a velocity of 4 mm/sec.

$$\text{velocity} = \frac{\Delta\ \text{distance}}{\text{time}} \quad \Rightarrow \quad \text{time} = \frac{\Delta\ \text{distance}}{\text{velocity}}$$

$$\text{acceleration} = \frac{\Delta\ \text{velocity}}{\text{time}} = \Delta\ \text{velocity} \bullet \frac{\text{velocity}}{\Delta\ \text{distance}}$$

Since the velocity starts from zero, Δ velocity = velocity.

$$\text{acceleration} = \frac{\text{velocity}^2}{\Delta\ \text{distance}} = \frac{4^2}{2} = 8\ \text{mm}/\text{sec}^2$$

Before starting to write the actual program, we need to consider one more thing: to assure a good result, the glue must start being dispensed while the motion is in progress. Thus, we have to start the motion first and then turn on the dispenser.

The motion we decide to perform is shown in **Fig. D.4**.

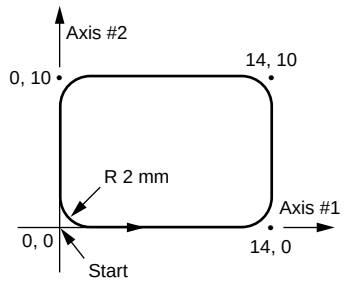
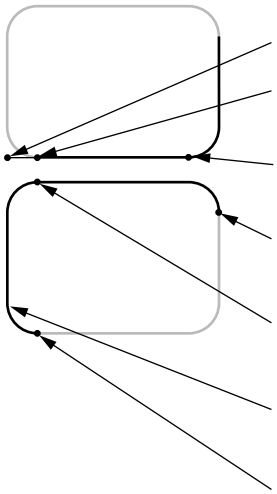


Fig. D.4— Desired Motion Result

The program will have the following listing:

1US1.0um	*define linear stage resolution 1.0 μm (axis 1)*
2US1.0um	*define linear stage resolution 1.0 μm (axis 2)*
1UUmm	*select millimeter as units (axis 1)*
2UUmm	*select millimeter as units (axis 2)*
EP	*enter programming mode and store all entries*
BO3	*define I/O bit 3 as output*
CB3	*clear output I/O bit 3 to zero*
1UP0; 2UP0; WA	*move axes # 1 and # 2 to absolute position 0 mm; wait for all axes to complete motion*
1UV4; 2UV4	*set velocity of axes # 1 and # 2 to 4 mm/sec*
1UA8; 2UA8	*set acceleration of axes # 1 and # 2 to 8 mm/sec²*
1UP14	*move axis # 1 to absolute position 14 mm*
1UW2; SB3	*wait for axis # 1 to reach position 2 mm; set bit # 3 (start glue)*
1UW12; 2UP10	*wait for axis # 1 to reach position 12 mm; start axis # 2 and move to position 10 mm*
2UW8; 1UP0	*wait for axis # 2 to reach position 8 mm; start axis # 1 and move to position 0 mm*
1UW2; 2UP0	*wait for axis # 1 to reach position 2 mm; start axis # 2 and move to position 0 mm*
2UW2; 1UP4	*wait for axis # 2 to reach position 2 mm; start axis # 1 and move to position 4 mm*
1UW2; CB3	*wait for axis # 1 to reach position 2 mm; clear bit # 3*
%	*end of program # 2; quit programming mode*



Appendix E
Daisy Chaining Multiple MM3000 RS232 Ports

The MM3000 provides support for daisy-chained RS232 serial communication. Up to 32 MM3000's may be controlled through one RS232 host terminal.

To operate in daisy-chained mode requires two conditions:

- Special cabling between the host computer and the various MM3000 units.
- Enabling the MM3000's for this mode and setting each unit address.

Cabling

For illustration purposes, three MM3000 are daisy chained below:

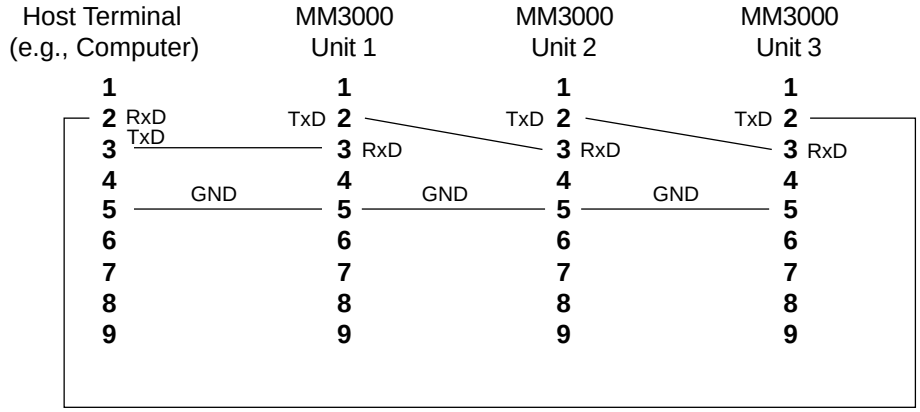


Fig. E.1—Required Cabling for 3 Controller Daisy-Chain

Enabling Daisy-Chained Mode

Before multiple units can be daisy chained, each unit must be set for this mode. This can be done three ways:

- With the front panel menu (see Section 2)
- With DC and AD commands (see Command Section)
- With a switch inside the unit

The preferred method is to use the front panel menu or the appropriate commands. If a user wishes to use the switches, proceed as follows.

Accessing the Switch:

WARNING

Opening or removing covers will expose you to hazardous voltages.

WARNING

Refer all servicing internal to this controller enclosure to qualified service personnel who should observe the following precautions before proceeding:

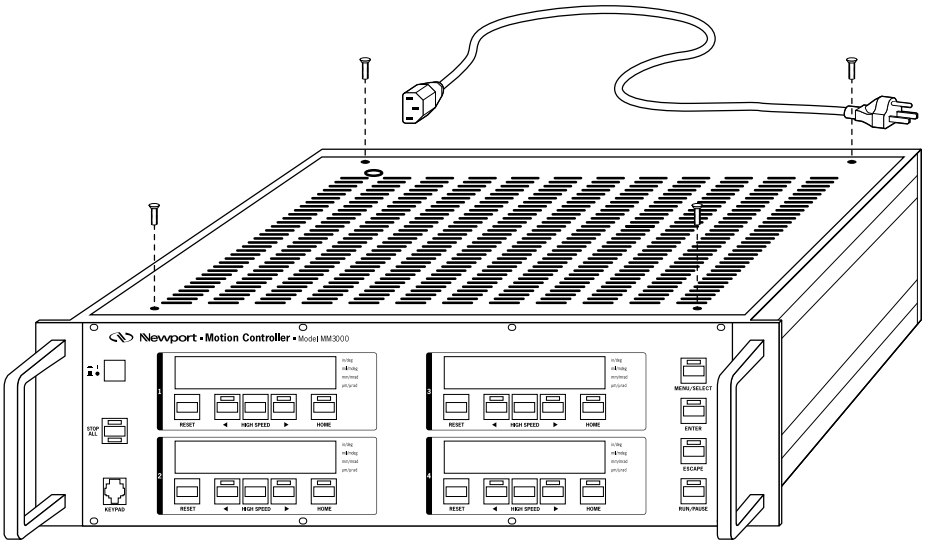
- **Turn power OFF and unplug the unit from its power source;**
- **Disconnect all cables;**
- **Remove any jewelry from hands and wrist;**
- **Use only insulated hand tools;**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

CAUTION

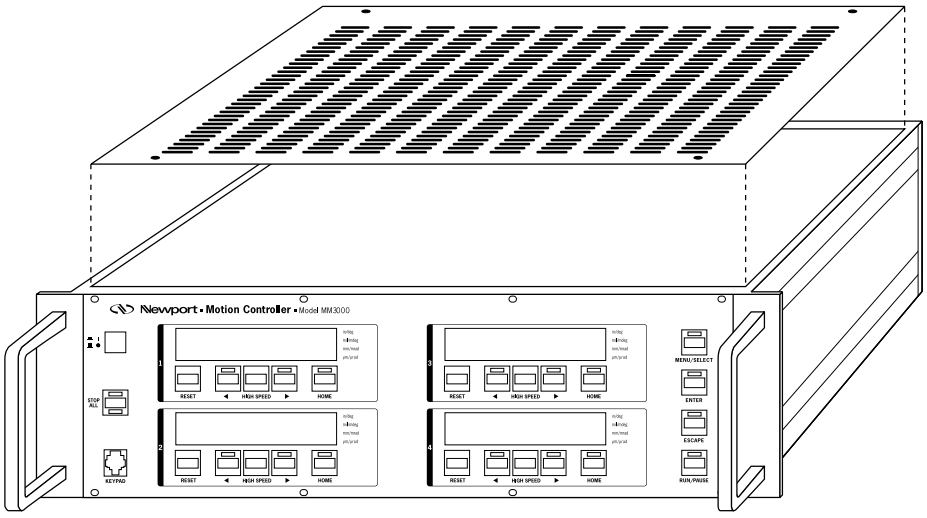
The MM3000 contains static sensitive devices. Exercise appropriate caution when handling MM3000 boards, cables and other internal components.

Before proceding to the next steps, unplug the power cord from the rear of the controller and do not plug in the cord until the unit is re-assembled again.

1. Remove the 4 screws on each corner of the cover.



2. Remove the top cover.



3. Locate switch S2.

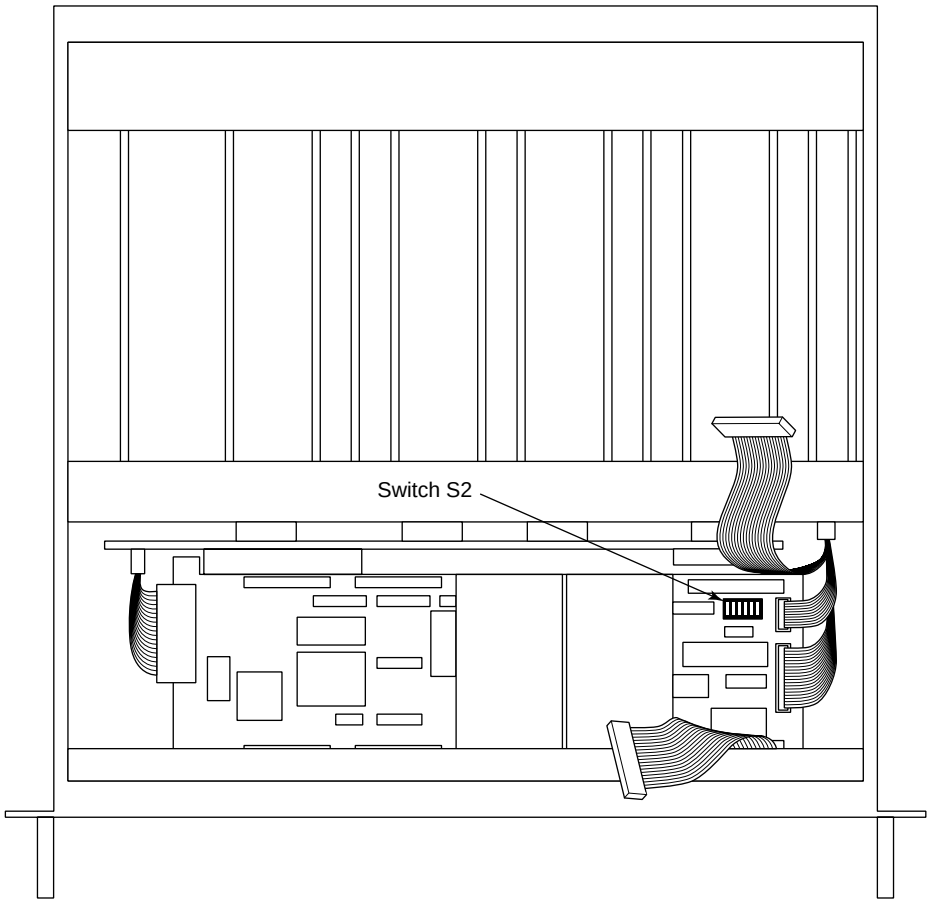
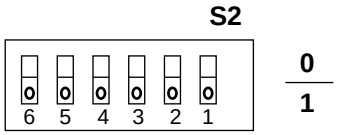


Fig. E.2—Top View of MM3000 with removed cover

Setting Address and enabling daisy-chain mode

S2.2 is the most significant bit and S2.6 is the least significant bit of the address. The address is derived as the binary equivalent of the switch settings. The table below shows a list of possible RS232 addresses:



Address	S2.2	S2.3	S2.4	S2.5	S2.6
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0
31	1	1	1	1	1

Figure E.3—Device Address Selection

Note: Switch S2.1 must be set to 1 to enable daisy chain mode.

Normally, the axis prefix for MM3000 commands has the range 1 to 4. However, in the daisy chain mode, the axis prefix is modified to provide a more logical numbering system. The effective axis prefix depends on the axis number and the MM3000 unit address:

Axis prefix = axis number + (unit address * 4)

For example, axis 1 in the MM3000 with address 2 will have an axis prefix of 9; i.e., Axis prefix = 1 + 4 • 2 = 9.

All commands sent to that axis must have the following format illustrated with the TP command:

```
9TP
```

Note that axis 9 will respond with 01>+0 (for example) because it is the first axis on unit 2.

Appendix F
IEEE-488 Setup

A typical IEEE-488 setup consists of an IEEE controller and several devices connected in parallel to the same bus. The IEEE-488 controller (e.g., computer) can selectively access any of these devices on the bus. To utilize this, each device on the bus needs to have a unique address.

The IEEE-488 address on the MM3000 can be set 3 different ways:

- In local mode using the menu (see Section 2)
- In remote mode using the *AD* command (see Command section).
- With DIP switch S2 inside the unit

NOTE

Due to GPIB protocol restrictions,
only 14 MM3000 units may occupy the same IEEE-488 bus.

Setting IEEE-488 Address with DIP Switch S2

WARNING

Opening or removing covers will expose you to hazardous voltages.

WARNING

Refer all servicing internal to this controller enclosure to qualified service personnel who should observe the following precautions before proceeding:

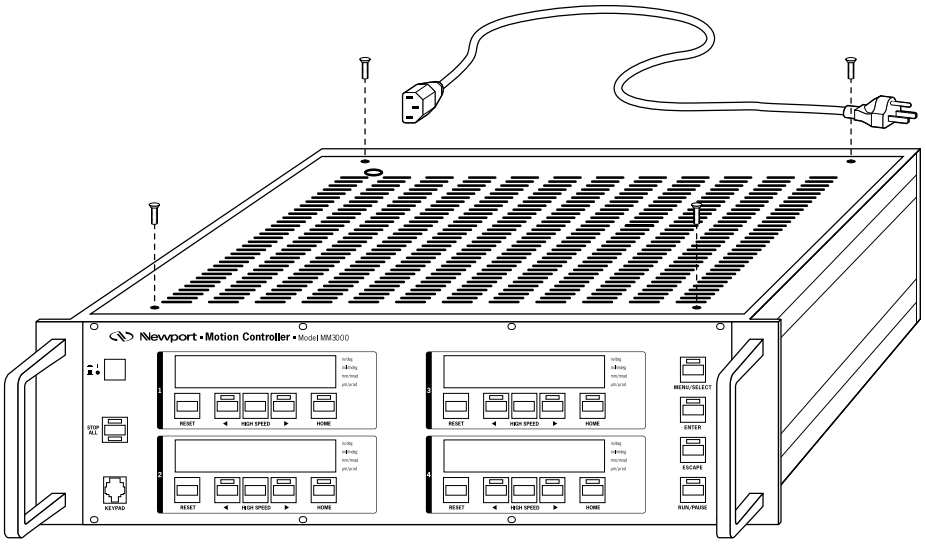
- **Turn power OFF and unplug the unit from its power source;**
- **Disconnect all cables;**
- **Remove any jewelry from hands and wrist;**
- **Use only insulated hand tools;**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

CAUTION

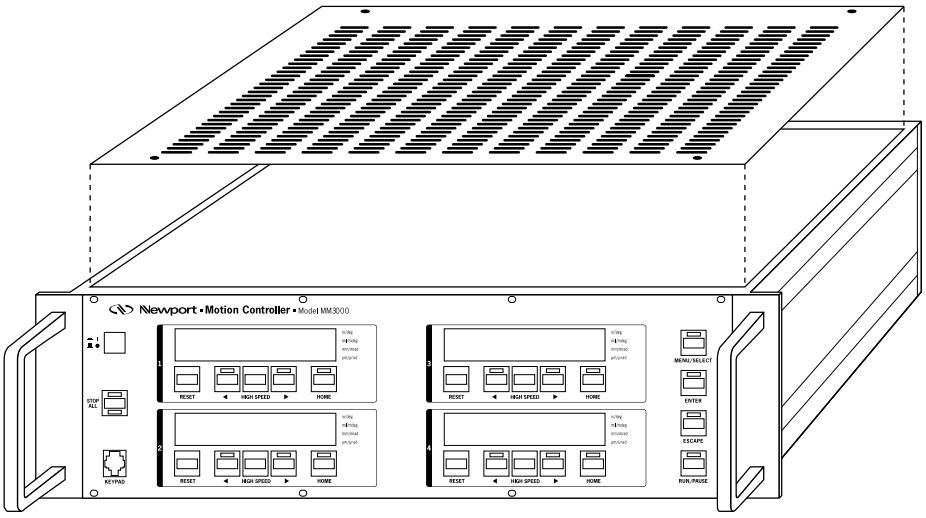
The MM3000 contains static sensitive devices. Exercise appropriate caution when handling MM3000 boards, cables and other internal components.

Before proceding to the next steps, unplug the power cord from the rear of the controller and do not plug in the cord until the unit is re-assembled again.

1. Remove the 4 screws on each corner of the cover.



2. Remove the top cover.



3. Locate switch S2.

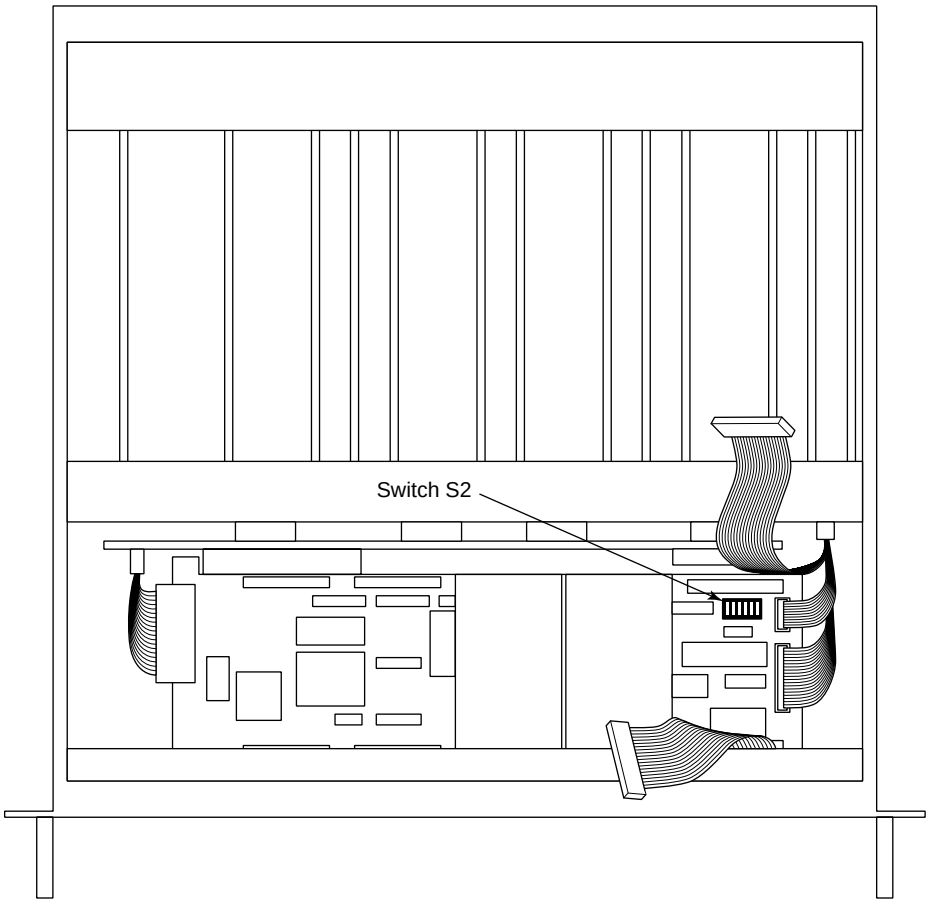
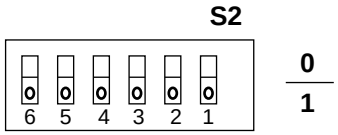


Fig. F.1—Top View of MM3000 with removed cover

4. Set Address

S2.2 is the most significant bit and S2.6 is the least significant bit of the address. The address is derived as the binary equivalent of the switch settings.



The table below shows a list of possible IEEE-488 addresses:

Address	S2.2	S2.3	S2.4	S2.5	S2.6
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0

Figure F.2—IEEE-488 Device Address Selection

NOTE

Switch S2.1 can be set either to 1 or 0 (don't care).

NOTE

Address 0 is typically reserved for the bus controller and is therefore not permitted as an M3000 address.

5. Reassemble unit

Appendix G
Troubleshooting Guide

Most of the time a blown fuse is the result of a more serious problem. Fixing the problem should include not only correcting the effect (blown fuse) but also the cause of the failure. Analyze the problem carefully to avoid repeating it in the future.

Following is a list of the most probable problems and their corrective actions. Use it as a reference but keep in mind that the cause of the problem might be a different one as listed below.

Problem	Cause	Corrective Action
Display LEDs do not come on	power switch is turned off	Turn on the power switch located on the front panel.
	no electrical power	Verify with an adequate tester or another electrical device (lamp, etc.) that power is present in the outlet.
	unplugged power cord	Plug the power cord in the appropriate outlet. Observe all caution notes and procedures described in Section 1.
	blown fuse	Replace the line fuse as described in Section 1. The fuse blows only when a problem arises. If the fuse blows again, contact Newport for service.
A connected axis is declared Unconnected	bad connection	Turn power off and verify the motion device cable connection.
	bad cable	Turn power off and swap the motor cable with another axis (if cables are identical) to isolate the problem. Contact Newport for cable replacement or motion device service.

Problem	Cause	Corrective Action
motor can not be turned on (underscore on the display does not disappear when motor power is turned on)	motor interlock connector on the rear of the MM3000 is missing	Plug connector in. If the connector was lost, you can build one as shown in Appendix B.
	excessive following error	Verify that the motion device installed is connected to the proper driver card.
		Verify that all setup parameters correspond to the actual motion device installed (see Appendix C).
		Verify that the specifications for the motion device are not being exceeded.
axis does not move	incorrect connection	Verify that the motion device is connected to the correct driver card, as specified by the labels.
	incorrect parameters	Verify that all relevant parameters (PID, velocity, etc.) are set properly (see Appendix C).
system performance below expectations	incorrect connection	Verify that the motion device is connected to the correct driver card, as specified by the labels.
	incorrect parameters	Verify that all relevant parameters (PID, velocity, etc.) are set properly.
motor excessively hot	incorrect connection	Verify that the motion device is connected to the correct driver card, as specified by the labels on the rear of the MM3000 and on the motion device.
move command not executed	software travel limit	The software limit (see SL command) in the specified direction was reached. If limits are set correctly, do not try to move past them.
	incorrect parameters	Verify that all relevant parameters (PID, velocity, etc.) are set properly.
home search not complete	faulty home or index signals	Carefully observe and record the motion sequence by watching the manual knob rotation, if available. With the information collected, call Newport for assistance.
no remote communication	wrong line terminator	Make sure that the computer and the controller use the same line terminator.
	wrong communication parameters	Verify that all communication parameters match between the computer and the controller.

NOTE

Many problems are detected by the controller and reported on the display and/or in the error register. Consult Appendix A for a complete list and description.

Appendix H
Decimal/ASCII/Binary Conversion Table

Some of the status reporting commands return an ASCII character that must be converted to binary. To aid with the conversion process, the following table converts all character used and some other common ASCII symbols to decimal and binary. To also help in working with the I/O port related commands, the table is extended to a full byte, all 256 values.

Number (decimal)	ASCII code	Hex code	Binary code	Number (decimal)	ASCII code	Hex code	Binary code
0	*null*	00	00000000	32	**space**	20	00100000
1	*soh*	01	00000001	33	**!**	21	00100001
2	*stx*	02	00000010	34	**“**	22	00100010
3	*etx*	03	00000011	35	**#**	23	00100011
4	*eot*	04	00000100	36	**$**	24	00100100
5	*enq*	05	00000101	37	**%**	25	00100101
6	*ack*	06	00000110	38	**&**	26	00100110
7	*bel*	07	00000111	39	**‘**	27	00100111
8	*bs*	08	00001000	40	**(**	28	00101000
9	*tab*	09	00001001	41	**)**	29	00101001
10	*lf*	0A	00001010	42	*****	2A	00101010
11	*vt*	0B	00001011	43	**+**	2B	00101011
12	*ff*	0C	00001100	44	**,**	2C	00101100
13	*cr*	0D	00001101	45	**-**	2D	00101101
14	*so*	0E	00001110	46	**.**	2E	00101110
15	*si*	0F	00001111	47	**/**	2F	00101111
16	*dle*	10	00010000	48	**0**	30	00110000
17	*dc1*	11	00010001	49	**1**	31	00110001
18	*dc2*	12	00010010	50	**2**	32	00110010
19	*dc3*	13	00010011	51	**3**	33	00110011
20	*dc4*	14	00010100	52	**4**	34	00110100
21	*nak*	15	00010101	53	**5**	35	00110101
22	*syn*	16	00010110	54	**6**	36	00110110
23	*etb*	17	00010111	55	**7**	37	00110111
24	*can*	18	00011000	56	**8**	38	00111000
25	*em*	19	00011001	57	**9**	39	00111001
26	*eof*	1A	00011010	58	**:**	3A	00111010
27	*esc*	1B	00011011	59	**;**	3B	00111011
28	*fs*	1C	00011100	60	**<**	3C	00111100
29	*gs*	1D	00011101	61	**=**	3D	00111101
30	*rs*	1E	00011110	62	**>**	3E	00111110
31	*us*	1F	00011111	63	**?**	3F	00111111

Number (decimal)	ASCII code	Hex code	Binary code	Number (decimal)	ASCII code	Hex code	Binary code
64	**@**	40	01000000	112	**p**	70	01110000
65	**A**	41	01000001	113	**q**	71	01110001
66	**B**	42	01000010	114	**r**	72	01110010
67	**C**	43	01000011	115	**s**	73	01110011
68	**D**	44	01000100	116	**t**	74	01110100
69	**E**	45	01000101	117	**u**	75	01110101
70	**F**	46	01000110	118	**v**	76	01110110
71	**G**	47	01000111	119	**w**	77	01110111
72	**H**	48	01001000	120	**x**	78	01111000
73	**I**	49	01001001	121	**y**	79	01111001
74	**J**	4A	01001010	122	**z**	7A	01111010
75	**K**	4B	01001011	123	**{**	7B	01111011
76	**L**	4C	01001100	124	**|**	7C	01111100
77	**M**	4D	01001101	125	**}**	7D	01111101
78	**N**	4E	01001110	126	**~**	7E	01111110
79	**O**	4F	01001111	127		7F	01111111
80	**P**	50	01010000	128		80	10000000
81	**Q**	51	01010001	129		81	10000001
82	**R**	52	01010010	130		82	10000010
83	**S**	53	01010011	131		83	10000011
84	**T**	54	01010100	132		84	10000100
85	**U**	55	01010101	133		85	10000101
86	**V**	56	01010110	134		86	10000110
87	**W**	57	01010111	135		87	10000111
88	**X**	58	01011000	136		88	10001000
89	**Y**	59	01011001	137		89	10001001
90	**Z**	5A	01011010	138		8A	10001010
91	**[**	5B	01011011	139		8B	10001011
92	\	5C	01011100	140		8C	10001100
93	**]**	5D	01011101	141		8D	10001101
94	^	5E	01011110	142		8E	10001110
95	**_**	5F	01011111	143		8F	10001111
96	**‘**	60	01100000	144		90	10010000
97	**a**	61	01100001	145		91	10010001
98	**b**	62	01100010	146		92	10010010
99	**c**	63	01100011	147		93	10010011
100	**d**	64	01100100	148		94	10010100
101	**e**	65	01100101	149		95	10010101
102	**f**	66	01100110	150		96	10010110
103	**g**	67	01100111	151		97	10010111
104	**h**	68	01101000	152		98	10011000
105	**i**	69	01101001	153		99	10011001
106	**j**	6A	01101010	154		9A	10011010
107	**k**	6B	01101011	155		9B	10011011
108	**l**	6C	01101100	156		9C	10011100
109	**m**	6D	01101101	157		9D	10011101
110	**n**	6E	01101110	158		9E	10011110
111	**o**	6F	01101111	159		9F	10011111

Number (decimal)	ASCII code	Hex code	Binary code	Number (decimal)	ASCII code	Hex code	Binary code
160		A0	10100000	208		D0	11010000
161		A1	10100001	209		D1	11010001
162		A2	10100010	210		D2	11010010
163		A3	10100011	211		D3	11010011
164		A4	10100100	212		D4	11010100
165		A5	10100101	213		D5	11010101
166		A6	10100110	214		D6	11010110
167		A7	10100111	215		D7	11010111
168		A8	10101000	216		D8	11011000
169		A9	10101001	217		D9	11011001
170		AA	10101010	218		DA	11011010
171		AB	10101011	219		DB	11011011
172		AC	10101100	220		DC	11011100
173		AD	10101101	221		DD	11011101
174		AE	10101110	222		DE	11011110
175		AF	10101111	223		DF	11011111
176		B0	10110000	224		E0	11100000
177		B1	10110001	225		E1	11100001
178		B2	10110010	226		E2	11100010
179		B3	10110011	227		E3	11100011
180		B4	10110100	228		E4	11100100
181		B5	10110101	229		E5	11100101
182		B6	10110110	230		E6	11100110
183		B7	10110111	231		E7	11100111
184		B8	10111000	232		E8	11101000
185		B9	10111001	233		E9	11101001
186		BA	10111010	234		EA	11101010
187		BB	10111011	235		EB	11101011
188		BC	10111100	236		EC	11101100
189		BD	10111101	237		ED	11101101
190		BE	10111110	238		EE	11101110
191		BF	10111111	239		EF	11101111
192		C0	11000000	240		F0	11110000
193		C1	11000001	241		F1	11110001
194		C2	11000010	242		F2	11110010
195		C3	11000011	243		F3	11110011
196		C4	11000100	244		F4	11110100
197		C5	11000101	245		F5	11110101
198		C6	11000110	246		F6	11110110
199		C7	11000111	247		F7	11110111
200		C8	11001000	248		F8	11111000
201		C9	11001001	249		F9	11111001
202		CA	11001010	250		FA	11111010
203		CB	11001011	251		FB	11111011
204		CC	11001100	252		FC	11111100
205		CD	11001101	253		FD	11111101
206		CE	11001110	254		FE	11111110
207		CF	11001111	255		FF	11111111

Appendix I
System Upgrades

The modular design of the MM3000 makes it easy for qualified individuals to upgrade the unit in the field to add axes. Preconfigured upgrade kits for specific motors are available upon request. Call Newport for details.

Section H.1 describes how to upgrade an MM3000 from 2 to 3 axes. Other axes upgrades can be performed accordingly.

WARNING

Opening or removing covers will expose you to hazardous voltages.

Refer all servicing internal to this controller enclosure to qualified service personnel who should observe the following precautions before proceeding:

- **Turn power OFF and unplug the unit from its power source;**
- **Disconnect all cables;**
- **Remove any jewelry from hands and wrist;**
- **Use only insulated hand tools;**
- **Maintain grounding by wearing a wrist strap attached to instrument chassis.**

CAUTION

The MM3000 contains static sensitive devices . Exercise appropriate caution when handling MM3000 boards, cables and other internal components.

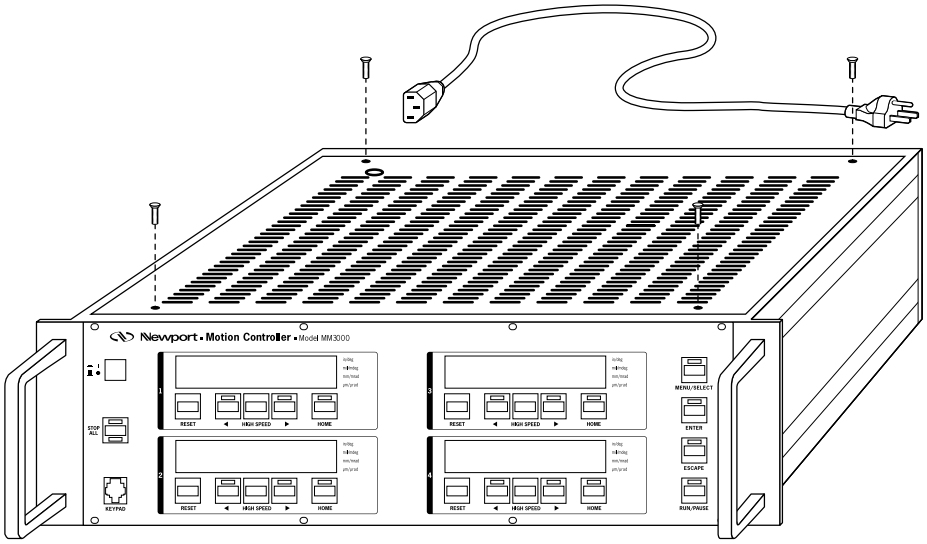
CAUTION

Do not install anything into your MM3000 except items provided by Newport specifically for installation into the MM3000.

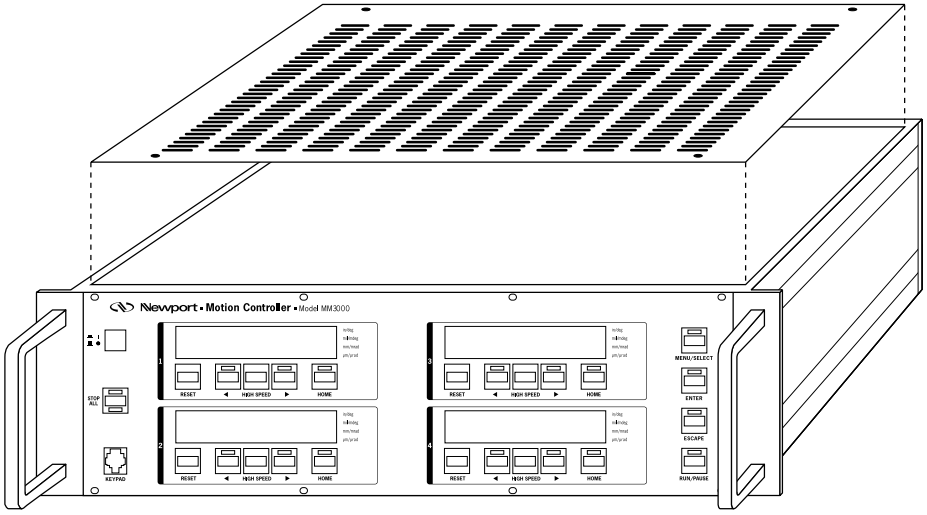
I.1 Adding a third axis

1. Turn the power off and unplug the power cord from the controller. Disconnect all cables from the controller.

2. Remove the 4 screws on the top cover as shown below.



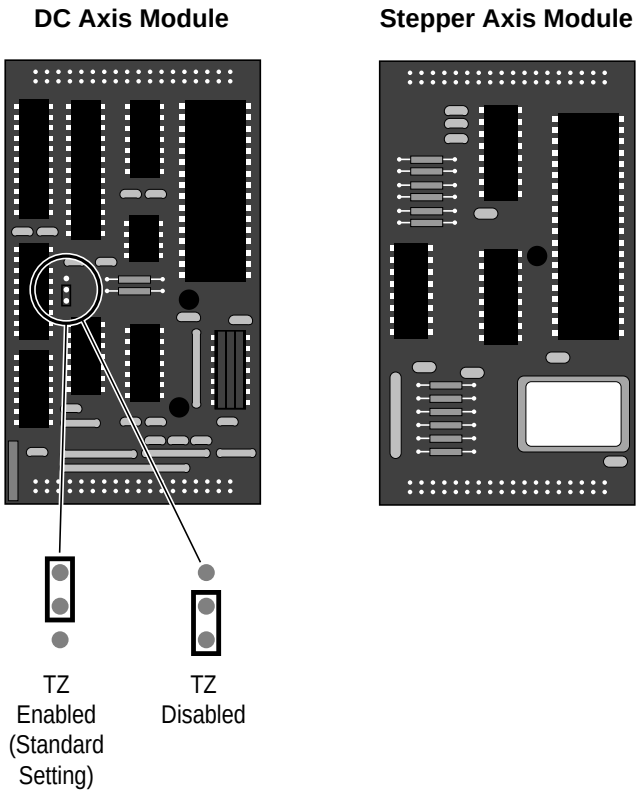
3. Carefully remove the top cover as shown below.



4. Next, the controller module for axis 3 has to be installed.

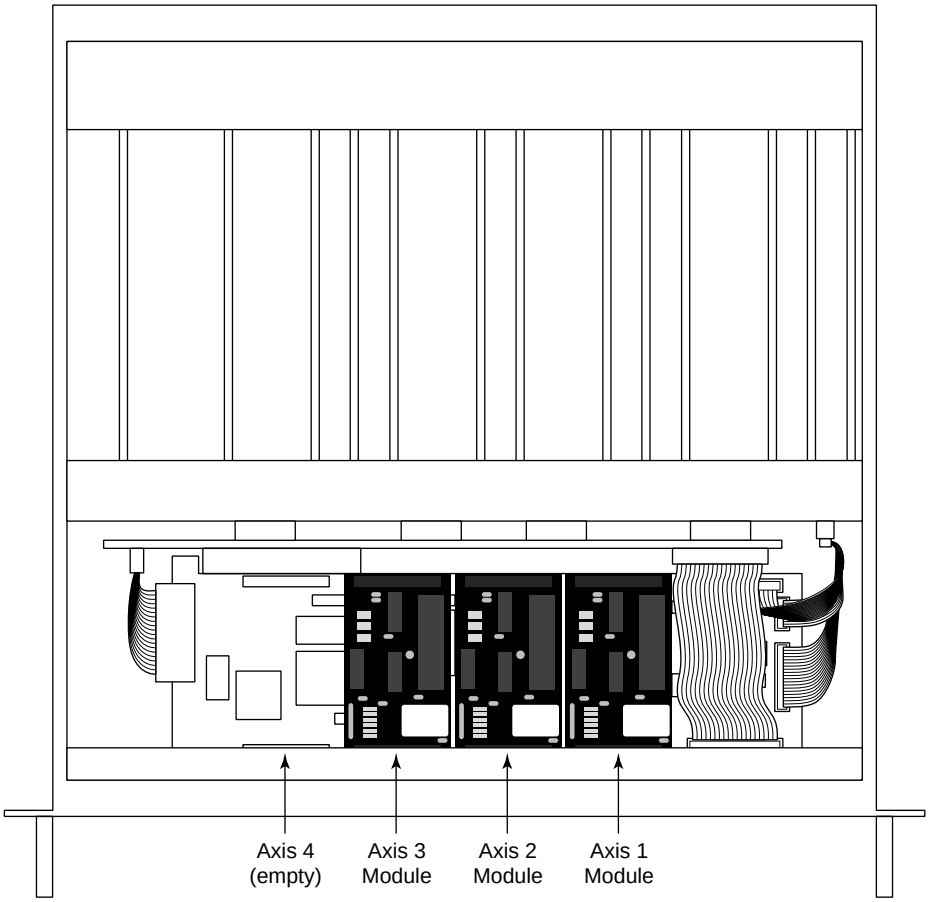
   There are 2 different modules:

   Stepper (P/N 070878) and DC (P/N 070884A). Make sure that you received the right module before installing it.

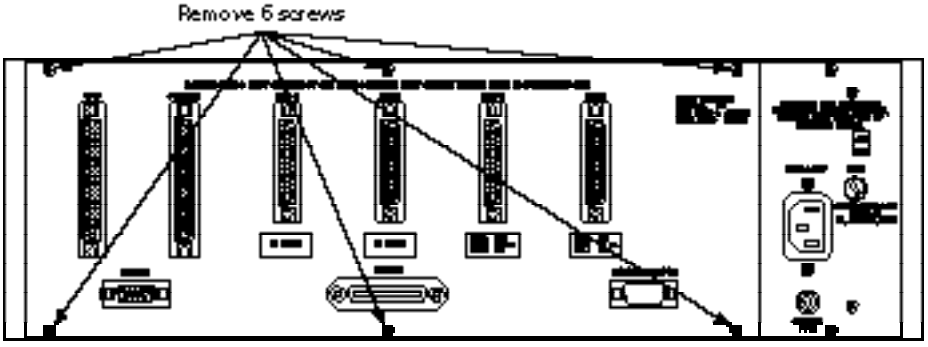


Insert the controller module for axis 3.

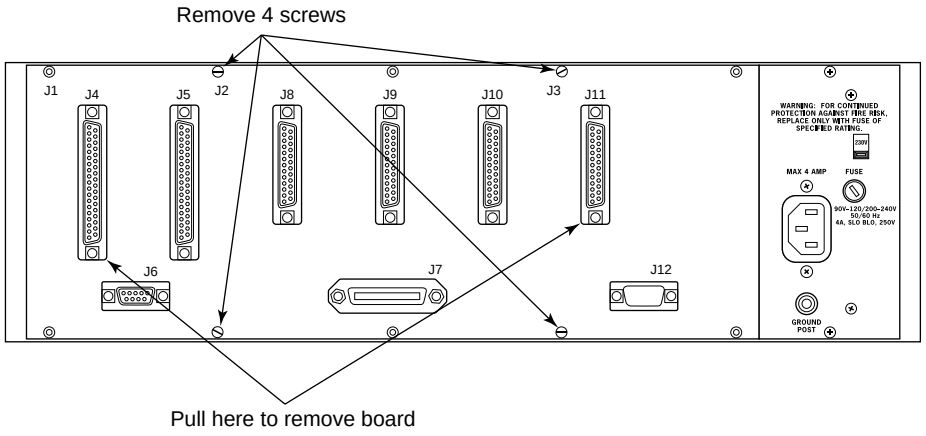
The connnector of the controller module is keyed to prevent insertion with improper polarity. Make sure the keys lign up properly before you try to insert the module.



5. Remove the rear panel by unscrewing the 6 screws as shown below.



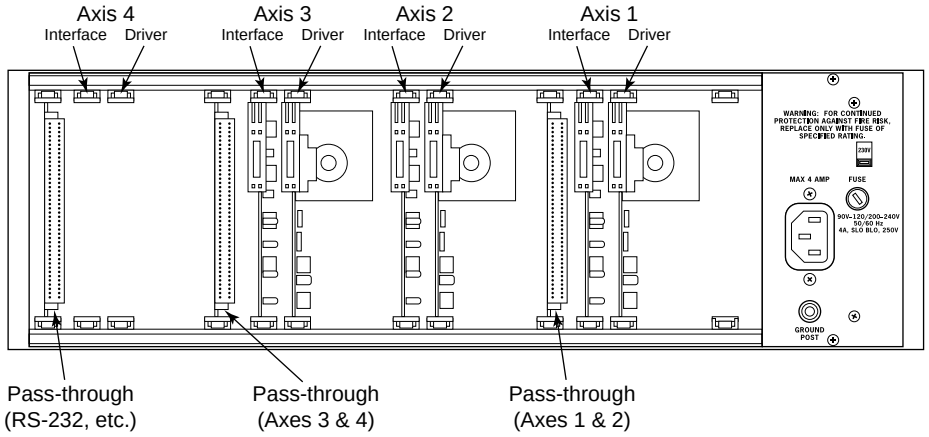
6. Remove the rear board by removing the 4 screws as shown below. Once the screws are removed, use the D-Sub connectors shown below to pull the rear board out of the enclosure.



7. The interior of the MM3000 should look similar to the figure below.

   Each axis consists of two boards: a driver board and an interface board. The driver board is installed on the right slot, the interface board on the left slot for each axis (see below).

   Plug in the interface board (P/N 41014A, 40001* or 40010*, where * denotes different versions of the same card, e.g., 40001A) into the interface slot for axis 3.



8. Install driver board.

   Plug the driver board (P/N 41014B, 41014C, 41014N, 40009*, 40011*, 40002* or 40004*) into the driver slot for axis 3.

9. Re-attach the rear board with the appropriate screws.

10. Re-attach rear panel with the appropriate screws.

11. Re-install top cover with the appropriate screws.

    The unit is now ready for use. Please read Section 1 for proper axis set-up before proceeding to connect a motor to the upgraded axis.

Appendix J
Factory Service

Introduction

This Section contains information regarding factory service for the MM3000. The MM3000 contains no user-serviceable parts. The user should not attempt any maintenance or service of this instrument and/or accessories beyond the procedures outlined in the **Troubleshooting Guide**, **Appendix G**. Any problem that cannot be resolved should be referred to Newport Corporation or your Newport representative for assistance.

Obtaining Service

To obtain information about factory service, contact Newport Corporation or your Newport representative. Please have the following information available:

1. Instrument model number (MM3000)
2. Instrument serial number
3. Firmware version number
4. Description of the problem

If the instrument is to be returned for repair, you will be given a Return Authorization Number, which you should refer to in your shipping documents. Please photocopy and fill out the service form on the next page and return the completed form with your system.

Service Form

Newport Corporation
U.S.A. Office: 714/863-3144
FAX: 714/253-1800

Name _____ RETURN AUTHORIZATION # _____
(Please obtain prior to return of item)

Company _____

Address _____ Date _____

Country _____ Phone Number _____

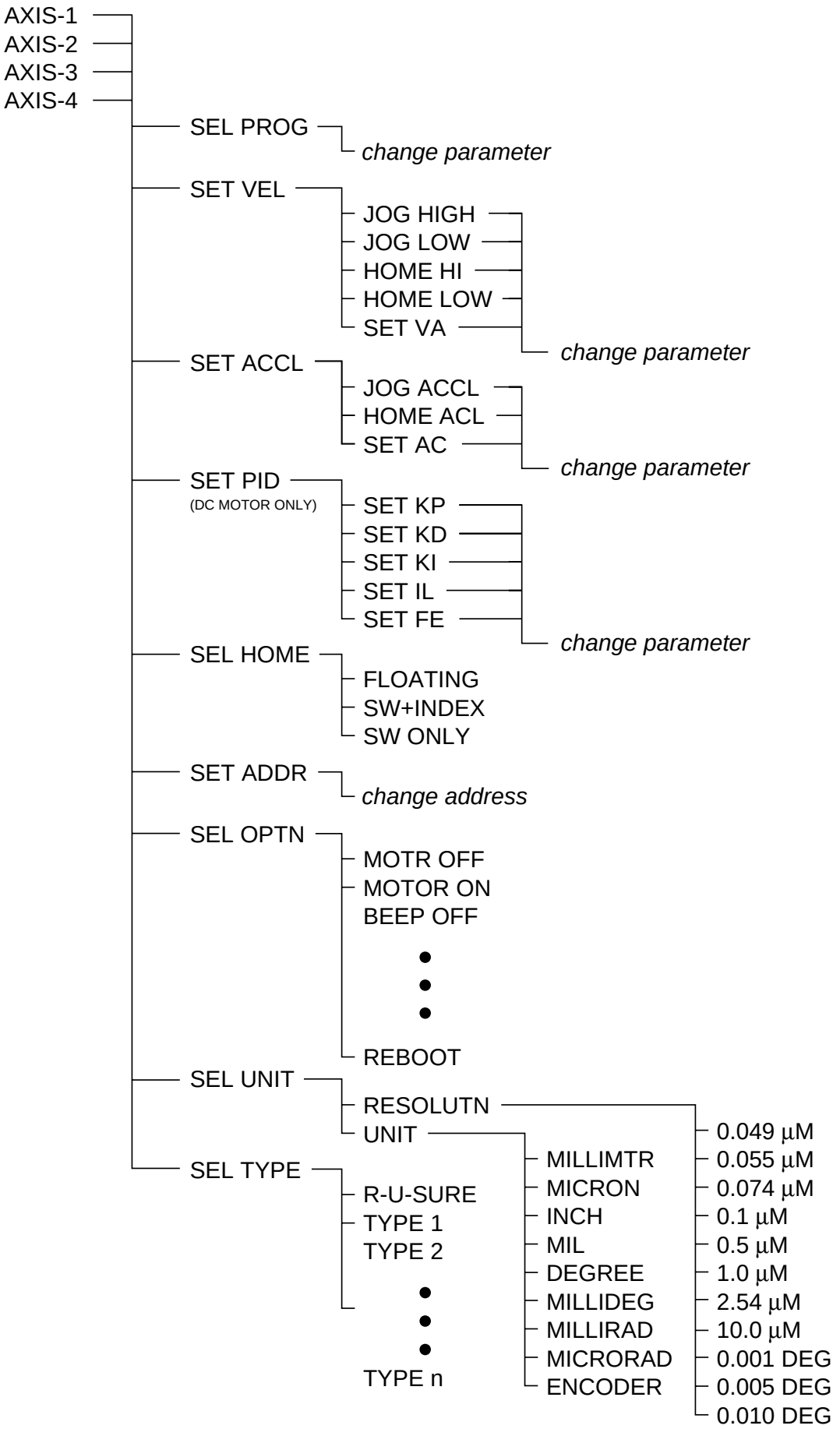
P.O. Number _____ FAX Number _____

Item(s) Being Returned:

Model # _____ Serial # _____

Description: _____

Reason for return of goods (please list any specific problems) _____


AXIS-1
AXIS-2
AXIS-3
AXIS-4
SEL PROG
change parameter
SET VEL
JOG HIGH
JOG LOW
HOME HI
HOME LOW
SET VA
change parameter
SET ACCL
JOG ACCL
HOME ACL
SET AC
change parameter
SET PID
(DC MOTOR ONLY)
SET KP
SET KD
SET KI
SET IL
SET FE
change parameter
SEL HOME
FLOATING
SW+INDEX
SW ONLY
SET ADDR
change address
SEL OPTN
MOTR OFF
MOTOR ON
BEEP OFF
REBOOT
SEL UNIT
RESOLUTN
UNIT
MILLIMTR
MICRON
INCH
MIL
DEGREE
MILLIDEG
MILLIRAD
MICRORAD
ENCODER
0.049 µM
0.055 µM
0.074 µM
0.1 µM
0.5 µM
1.0 µM
2.54 µM
10.0 µM
0.001 DEG
0.005 DEG
0.010 DEG
SEL TYPE
R-U-SURE
TYPE 1
TYPE 2
TYPE n

MM3000 Command List by Category

Cmd.	Description	IMM	PGM	MIP	Page
Motion					
AB	Abort motion	■	■	■	3.17
AC	Set acceleration	■	■	□	3.18
JA	Set jog acceleration	■	■	■	3.52
JH	Set jog high speed	■	■	■	3.53
JW	Set jog low speed	■	■	■	3.55
ML	Move to travel limit	■	■	■	3.63
MV	Move indefinitely	■	■	■	3.66
MZ	Move to index pulse	■	■	■	3.67
OA	Set origin search acceleration	■	■	■	3.68
OH	Set origin search high velocity	■	■	■	3.69
OL	Set origin search low velocity	■	■	■	3.70
OR	Perform origin search	■	■	□	3.72
PA	Position absolute	■	■	■	3.74
PR	Position relative	■	■	■	3.77
SD	Speed divide	■	■	■	3.89
ST	Stop motion	■	■	■	3.93
VA	Set velocity value	■	■	■	3.121
VB	Set base velocity: start/stop velocity	■	■	■	3.122
VR	Increment/decrement present velocity	■	■	■	3.124
VS	Sample-time velocity mode	■	■	■	3.125
Motion in Units					
UA	Set unit acceleration	■	■	□	3.110
UP	Move to absolute unit position	■	■	■	3.113
UR	Units position relative	■	■	■	3.115
US	Define resolution	■	■	□	3.117
UU	Select positioning unit	■	■	□	3.118
UV	Set unit velocity	■	■	■	3.119
Motion Related					
BA	Enable backlash compensation	■	■	□	3.20
CL	Enable closed loop stepper	■	■	□	3.24
CO	Enable linear compensation	■	■	□	3.27
DH	Define home	■	■	■	3.31
DS	Derivative sampling interval	■	■	■	3.34
FE	Set following error threshold	■	■	■	3.40
IL	Set integration limit	■	■	■	3.51
JY	Enable joystick control	■	■	■	3.56
KD	Set PID Derivative constant	■	■	■	3.57
KI	Set PID Integration constant	■	■	■	3.58
KP	Set PID Proportional constant	■	■	■	3.59
MF	Turn motor power off	■	■	■	3.62
MO	Turn motor power on	■	■	■	3.64
OV	Set overshoot value for home search	■	■	■	3.73
SE	Simultaneous command execution	■	■	■	3.90
SL	Set soft (travel) limits	■	■	■	3.91
SY	Set axes for simultaneous execution	■	■	■	3.95
TY	Select stage type	■	■	□	3.109
UF	Update PID filters	■	■	■	3.112
Programming					
CM	Create macro	■	□	■	3.26
CP	Compile program	■	□	□	3.28
EM	Execute macro	■	■	□	3.36
EP	Enter program mode	■	□	□	3.37
EX	Execute program	■	□	□	3.39
IE	Initialize time interval execution mode	■	■	■	3.49
LM	List all macro definitions	■	■	■	3.60
LP	List stored program	■	□	■	3.61
PE	Power-on execution	■	□	□	3.76
QP	Quit program execution mode	■	□	□	3.79
/QP	Program delimiter	□	■	□	3.80
RM	Reset all macro definitions	■	■	■	3.84
RQ	Generate interrupt	■	■	■	3.86
SV	Set variable value	■	■	■	3.94
%	Quit program entry mode	■	□	□	3.134
‘	Program line comments	□	■	□	3.135

Cmd.	Description	IMM	PGM	MIP	Page
Reporting					
DA	Tell desired acceleration	■	■	■	3.29
DP	Tell desired position	■	■	■	3.33
DV	Tell desired velocity	■	■	■	3.35
MS	Tell motor status	■	■	■	3.65
RA	Read analog channel	■	■	■	3.81
RB	Read I/O bits	■	■	■	3.82
RC	Report module configuration	■	■	■	3.83
TB	Tell error buffer contents	■	■	■	3.96
TE	Tell error code	■	■	□	3.97
TF	Tell filters (PID)	■	■	■	3.98
TL	Tell soft limits and following error	■	■	■	3.100
TM	Tell memory usage	■	■	■	3.101
TP	Tell actual position	■	■	■	3.102
TPE	Tell positon in encoder units	■	■	■	3.103
TPI	Tell position in motor step units	■	■	■	3.104
TR	Initialize motion tracing mode	■	■	■	3.105
TS	Tell status	■	■	■	3.106
TT	Tell motion trace data	■	■	□	3.107
TV	Tell velocity	■	■	■	3.108
VE	Tell firmware version	■	■	■	3.123
Sequence					
DL	Define label	□	■	□	3.32
IF/ THEN	IF condition THEN goto label	□	■	■	3.50
JL	Jump to label	□	■	■	3.54
RP	Repeat previous command	■	■	■	3.85
UW	Wait for position crossing in units	■	■	□	3.120
WA	Wait for all axes to stop	■	■	■	3.126
WB	Wait bit level, then execute	■	■	■	3.127
WHILE/ WEND	WHILE bit(s) high/low ...WEND	■	■	■	3.129
WP	Wait for position, then execute	■	■	■	3.130
WS	Wait for stop, then execute	■	■	■	3.131
WT	Wait time, then execute next command	■	■	■	3.132
Miscellaneous					
AD	Set address	■	■	■	3.19
BI	Define input bits	■	■	■	3.21
BO	Define output bits	■	■	■	3.22
CB	Clear bits	■	■	■	3.23
DC	Enable/disable daisy-chaining	■	■	■	3.30
ER	Set encoder ratio	■	■	□	3.38
FI	Format interrupt	■	■	■	3.41
FM	Format motion	■	■	■	3.43
FO	Format output	■	■	■	3.45
FS	Format system	■	■	■	3.47
OM	Set home search type	■	■	■	3.71
RS	Reboot system	■	■	■	3.87
SB	Set bits high	■	■	■	3.88
SR	Select baud rate	■	■	■	3.92
TG	Toggle bits	■	■	■	3.99
WD	Write value to D/A channel	■	■	■	3.128
XX	Purge memory	■	□	□	3.133
#	Emergency stop	■	□	■	3.136

IMM = Immediate Mode PGM = Program Mode MIP = Motion in Progress